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Astronomy[®]

AMERICA'S BEST-SELLING ASTRONOMY MAGAZINE

April 2002

Inflation

The Complete Story

Take the
Savvy Astronomer
Challenge on page 80

Exotic Eclipse
of 2002

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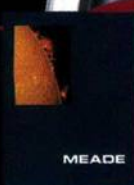
LX200GPS

MEADE®

A NEW WORLD STANDARD



Right-to-left: Meade 8", 10", and 12" LX200GPS Schmidt-Cassegrain telescopes. Manufactured under U.S. Patent No. 6,304,376; other patents pending in the U.S.A. and worldwide.



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Meade® LX200GPS: the most important advance in Schmidt-Cassegrain technology in ten years is here.

For the visual observer, the astrophotographer, the CCD imager: all the telescope you could possibly have imagined.

For the advanced amateur, new Meade LX200GPS telescopes offer absolutely state-of-the-art optical, mechanical, and electronic performance unmatched by any competing models. Standard-equipment features include:

Precision GPS Alignment: Telescope alignment is accomplished automatically using integrated true-level and North electronic sensors in combination with a 16-channel GPS receiver located in the left-hand fork arm. Magnetic declination compensation is

Meade Zero Image-Shift Microfocuser operates at 4 different speeds from extremely slow to fast and is actuated through the Autostar II handbox. Coarse manual focusing is effected through the telescope's manual focus knob.

Autostar II: The new Autostar II control system provided with LX200GPS models includes all of the features that made previous LX200 models the largest-selling serious telescopes in the world. In addition, Autostar II includes an expanded 3.5 Megabyte memory, with a greatly enlarged database of more than 145,000 celestial objects, a database that is immediately accessible on the Autostar II display. A partial listing of the Autostar II database:

Library	No. of Objects
New General Catalog (NGC)	7840
Index Catalog (IC)	5386
Uppsala Galaxy Catalog	12,940
Morphological Catalog of Galaxies	12,939
General Catalog of Variable Stars	28,484
SAO and Hipparcos Star Catalogs	31,090
Messier Catalog (M)	110
Caldwell Catalog	109
Named Objects	227
Herschel Catalog	400
Abell Catalog of Galaxy Clusters	2712
Arp Catalog of Irregular Galaxies	645



All LX200GPS models include the Zero Image-Shift Microfocuser as standard equipment.

designed into the software and automatically engaged. Just press the ENTER button on the Autostar II hand controller and watch as the telescope slews at 8°/second to its first alignment star. Competing GPS telescopes use a 12-channel receiver (resulting in slower and less reliable position acquisition), do not include any magnetic declination compensation, and can easily result in first-alignment-star errors of up to 20° or more.

Revolutionary new rear-cell systems designed for the advanced visual observer, astrophotographer and CCD imager — systems that enable new levels of precision in focusing in all applications and in image centering on CCD chips:

Primary Mirror Lock: Flip a knob located just above the manual coarse-focus knob and lock the telescope's primary mirror rigidly in place. Used in conjunction with the Zero Image-Shift Microfocuser (below) the primary mirror lock cancels any residual image shift while focusing during visual, photographic, or CCD imaging applications.

Zero Image-Shift Microfocuser: Now you can obtain the most precise image focus possible — truly to a microscopic level — during visual and astrophotographic applications, and, during CCD applications, simultaneously maintain precise image centering on even the smallest CCD chips. Included as standard equipment with all LX200GPS Schmidt-Cassegrain models, the

SPECIFICATIONS: 7", 8", 10", and 12" LX200GPS — Each complete telescope includes 8", 10", or 12" f/10 Schmidt-Cassegrain or 7" f/15 Maksutov-Cassegrain optical tube assembly with EMC super multi-coatings; primary mirror lock; 4-speed zero image-shift microfocuser; heavy-duty fork mount with 4" polar ball bearing, dual-axis 5.75" worm gears, and 7-port multi-function control panel, including two RS-232 serial interface ports; manual and electric slow-motion controls on both axes; Autostar II control system with 3.5 Megabyte flash memory, digital readout display, permanently programmable Smart Drive and 9-speed drive controls on both axes, High-Precision Pointing, and GO TO controller; 145,000-object onboard celestial software library; 12VDC telescope power supplied from internal battery compartments accepting 8 (user-supplied) C-cells (optional 25 ft. cords are available for powering from auto cigarette lighter plug or from 115VAC); 8 x 50mm viewfinder; 1.25" diagonal prism (7", 8", 10") or 2" diagonal mirror with 1.25" adapter (12"); Series 4000 Super Plössl 26mm eyepiece; standard field tripod (7", 8", 10") or giant field tripod (12"); operating instructions.

INTRODUCTORY PRICES

MEADE LX200GPS

SCHMIDT-CASSEGRAIN TELESCOPES

8" LX200GPS	\$2495
10" LX200GPS	2995
12" LX200GPS	3995
7" LX200GPS Maksutov-Cassegrain	2995

Packing & shipping charges in the 48 states: 8" — \$105; 10" — \$145; 12" — \$215; 7" — \$125. Prices shown are suggested U.S. national mail-order retail prices.

A COMPARISON OF GPS SCHMIDT-CASSEGRAIN TELESCOPES

	Meade LX200GPS	Competing 11" GPS*
GPS Receiver	16-channel	12-channel
Magnetic declination compensation	yes	no
True-level electronic sensor	yes	no
Primary mirror lock	yes	no
Zero image-shift microfocuser	yes	no
Maximum slew speed	8°/second	3°/second
Memory	3.5-Meg flash	1.0-Meg flash
GO TO pointing precision	2-arcmins	unstated
High-precision pointing mode	yes; permits GO TO pointing precision within 1-arcmin	no
Permanent Periodic Error Correction	yes, both axes	one axis only; second axis unprogrammable
Object database	145,000 objects	"40,000+"
Encoder resolution	0.14 arcsecs	0.26 arcsecs
Internal battery compartments for battery powering	yes; batteries located internal to fork arms	no
RS-232 software download	yes; object libraries and software downloads available	not currently available on factory website**
Tracking calibration	not required	recommended after changes in telescope position or load

*Based on sample and instruction manual received in 7/01. **As of 1/5/02.

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ASTRONOMICS, Norman, OK.
Orders: 800-422-7876; Info.: 405-364-0858.

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OCEANSIDE PHOTO & TELESCOPE, Oceanside, CA.
Orders & Information: 800-483-6287.

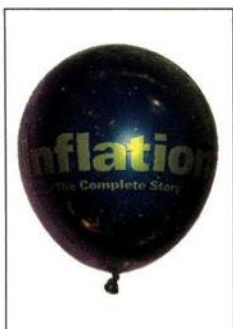
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SHUTAN CAMERA & VIDEO, Chicago, IL.
Orders & Info.: 800-621-2248; IL: 847-367-4600.

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EFSTONSCIENCE, Toronto, Ontario, Canada
Orders & Information: 416-787-4581.

KHAN SCOPE CENTRE, Toronto, Ontario, Canada
Orders & Information: 416-783-4140.



Astronomy

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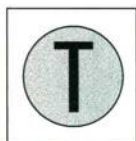


70 Celestial Portraits: Hydra

From *The Glorious Constellations*, © 1991; Harry N. Abrams, Inc.



Special Delivery on Inflation



The budding universe, much too small yet to be visible, began to expand faster than the speed of light. In a minuscule part of a second, the universe doubled in size 100 times, explains writer Steve Nadis in "Cosmic Inflation Comes of Age," (see page 28). But almost as quickly as it began, this process called inflation ended, releasing energy destined to become radiation and matter.

We decided six months ago to devote an issue to the current thinking about inflation theory and its relationship to the Big Bang. In addition to the Nadis piece, we collected stories that would tell the history of how inflation theory evolved (for the most part) to fill the gaps in the Big Bang theory. We also commissioned profiles of the researchers involved, and some short, sweet stories about digressions and departures from the mainstream — if you can believe there is a mainstream.

Once all the manuscripts arrived, we realized we would have enough words to fill many pages and precious few photos, since no one has yet captured an image of the Big Bang. Rethinking the special report led to an altogether new way of doing things.

The stories that appear on paper in this issue include "Cosmic Inflation Comes of Age," "Is Inflation Supernatural?" and "The Search for A Final Theory." To find out what contributing editor Jim Trefil has to say on the history of inflation theory, though, you must go online to Astronomy.com and select Astronomy magazine. At Astronomy.com, you also will find short profiles and photos of the scientists who have done much of the inflation work.

We hope you enjoy this new presentation. Please contact us to let us know.

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ETX-105EC with Electronic
Controller (shown)...\$695
Optional #497 Autostar...\$149

Prices shown are suggested
U.S. mail-order retail prices.



ETX-70AT with standard-
equipment #494 Autostar
Controller...\$349



ETX-90EC with Electronic
Controller...\$495. Optional #497
Autostar (shown)...\$149



ETX-125EC with Electronic
Controller...\$895. Optional #497
Autostar (shown)...\$149

An ETX is astronomy made simple!

1. Enter on the Autostar display the astronomical object you want to see.
2. Press GO TO.
3. Watch as the telescope moves to the object and places it in the field of view — automatically!

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LXD55

MEADE

6" 8" 10"

SCHMIDT-NEWTONIANS WITH AUTOSTAR®

Now you can buy a Meade Schmidt-Newtonian telescope with Autostar dual-axis GO TO drive system for as little as \$599, complete!



Shown: Meade 8" f/4 LXD55 Schmidt-Newtonian Telescope with standard-equipment Autostar Control System

MEADE LXD55 SCHMIDT-NEWTONIAN TELESCOPES

Shipped complete per specifications below:

6" LXD55 Schmidt-Newtonian	\$599
8" LXD55 Schmidt-Newtonian	729
10" LXD55 Schmidt-Newtonian	879

Packing & shipping charges in the 48 states: 6" - \$75; 8" - \$85; 10" - \$95. Prices shown are suggested U.S. national mail-order retail prices.

SPECIFICATIONS: 6", 8", and 10" LXD55-Series Telescopes — Each complete telescope includes 6" f/5, 8" f/4, or 10" f/4 Schmidt-Newtonian optical tube assembly with EMC super multi-coatings; quick-attach cradle ring assembly with locks; 6 x 30mm achromatic viewfinder; all-metal rack-and-pinion focuser with eyepiece holders for both 1.25" and 2" eyepieces; Series 4000 Super Plössl 26mm eyepiece. LXD55 German-type equatorial mount with worm gear drives and electric slow-motion controls on both axes; micrometric controls for azimuth and elevation adjustments; illuminated polar alignment finder with reticle; variable-height field tripod with accessory shelf. Autostar dual-axis control system with digital readout display; 9-speed drive controls; 30,223-object celestial software library and automatic GO TO object-locating. Battery pack accepting eight (user-supplied) D-cells (optional 25 ft. cords permit powering from either 12vDC auto cigarette lighter plug or from 115vAC home outlet); operating instructions.



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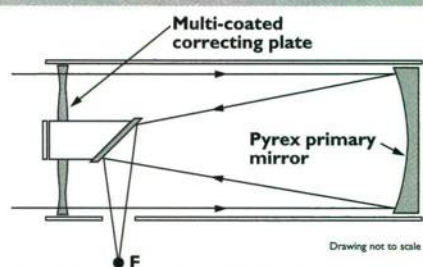
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Every Meade LXD55-Series Schmidt-Newtonian telescope includes this listing of standard equipment:

Schmidt-Newtonian optical systems: Manufactured entirely at the Meade Irvine facility, LXD55 diffraction-limited Schmidt-Newtonian optics yield pinpoint stellar images over extremely wide fields, with *one-half* the coma of paraboloids of the same focal ratios. Combined with fast f/4 (8", 10") or f/5 (6") optics, the standard-equipment Super Plössl 26mm eyepiece yields an actual field in excess of 1.3°, for brilliant, rich-field imaging of nebulae, galaxies, and star clusters. High-power lunar and planetary images



The Meade Schmidt-Newtonian Optical System.

reveal subtle detail often lost in telescopes of lesser optical resolution. The optics are mounted in machined aluminum cells fitted to white-enameled metal tubes; each tube accepts the giant Meade

rack-and-pinion focuser with eyepiece holders for both 1.25" and 2" eyepieces.

LXD55 Equatorial Mount: Designed by Meade engineers and manufactured of machined aluminum for high-performance photo-visual observing, the new Meade LXD55 mounting moves effortlessly across the skies in either tracking or automatic GO TO modes. Included is an illuminated polar viewfinder for quick, precise polar alignment.



All LXD55 telescopes include an illuminated polar alignment finder as standard equipment.

Autostar Dual-Axis Electronic Control System: A revelation of advanced electronic and software design, the exclusive patent-pending Meade Autostar system, included as standard equipment with every LXD55 telescope, permits an amazing range of capabilities never before offered on telescopes in this price and aperture class:

Automatic GO TO capability at 4.5"/second on both axes simultaneously, to 30,223 database objects, including:

13,235 deep-sky objects — galaxies; diffuse and planetary nebulae; star clusters; the complete Messier, Caldwell, IC, and NGC catalogs.

16,888 stars sorted by name, SAO catalog numbers, double and variable stars.

50 objects in the Solar System; 8 major planets from Mercury to Pluto; the Moon; 26 asteroids; 15 comets.

50 Earth satellites; 200 memory locations for user-defined objects.

Automatic GO TO capability to any object of known R.A. and Declination.

Nine selectable slew and slow-motion speeds: 4.5°, 3°, and 1.5°/sec, 128x, 64x, 16x, 8x, 2x, and 1x sidereal.

Automatic sidereal-rate tracking in R.A. keeps objects precisely centered in the field.

Control of the telescope through your PC and full upgradability over the Internet, using the RS-232 serial interface. (Requires optional #505 Connector Set.)

Battery Pack (12vDC): Included with each LXD55 telescope; rests on the telescope's accessory shelf and plugs into the control panel. The battery pack accepts eight (user-supplied) D-cell batteries, which power the telescope for more than 40 hours.

Astrophotography and CCD imaging: Armed with their fast photographic speeds, Meade LXD55 Schmidt-Newtonians are ideally suited for deep-space astrophotography and CCD imaging at the telescope's prime focus.



The LXD55 control panel is located below the upper bearing of the polar axis.

Below, left to right: Meade 6" f/5, 8" f/4, and 10" f/4 LXD55 Schmidt-Newtonian telescopes. Each telescope is shipped complete with all equipment shown.



Meade LXD55 Schmidt-Newtonians open up the skies to images and capabilities previously unavailable in telescopes of their aperture and price level. Consider what a Meade LXD55 telescope can do for your observing program:

6" LXD55 — Observe *hundreds* of galaxies, nebulae, and star clusters of all types *your very first night out*, and hundreds more the next night out, simply by pressing the Autostar GO TO pushbutton. Watch as the telescope moves effortlessly and automatically from major planet to asteroid to galaxy to nebula at 4.5"/second, placing every object in the center of the telescopic field. Study fine fault lines on the Moon, structural detail in Jupiter's cloud belts and Red Spot, the Cassini division in Saturn's rings, and much more.

8" LXD55 — With 78% more light-gathering power than the 6" model, the 8" LXD55 roughly triples the number of observable objects in deep-space and resolves extremely fine planetary detail as well: Jupiter's cloud belts are seen as a web of intricate discontinuities; transits and shadow transits of Jupiter's main satellites are observable; six of Saturn's satellites may be seen in revolution about the planet. Deep-space phenomena take on new character with the larger 8" aperture, as Autostar moves the telescope automatically from one spectacular object to the next. CCD images at the telescope's prime f/4 focus show a new level of resolution and detail after only a few minutes' exposure.

10" LXD55 — A quantum leap in image brightness and resolution, the 10" LXD55 provides for a lifetime of serious study in deep-space or within the Solar System. Use Autostar to take an automatic tour, on any given evening, of, say, the 200 brightest diffuse nebulae, spiral galaxies, and globular star clusters. Or, with Autostar's pushbutton electronic slow-motion controls, scan the surface of the Moon at high magnification. Let Autostar locate and center in the field the outer planets Uranus and Neptune, now visible as finite-sized orbs, or Pluto, at the telescope's very limit of observability. It is an uncommon observer who might outgrow the capabilities of the Meade 10" LXD55.

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MEADE®

RESEARCH-GRADE ACCESSORIES

Series 4000™ Super Plössl

52° field; multi-coated



Meade 4-element Super Plössl, updated and redesigned to utilize the latest in optical glass-types, are the finest general-purpose eyepieces available. For observing headline lunar and planetary detail, splitting close doubles, or for deep-space; guaranteed to deliver more contrast and image sharpness than any other brand. Rubber eyeguards fold down for eyeglass wearers—a feature not available on competing brands. Multi-coated. All focal lengths through 32mm are parfocal.

Super Plössl (SP; 4-elements; 1.25°; 52°):
6.4, 9.7, 12.4, 15, 20, 26mm
32mm (52°); 40mm (41°)
56mm (52°; 2°)

each: \$79.95 (4.54)
each: \$99.95 (5.26)
\$199.95 (7.02)

Series 4000™ Ultra Wide Angle

84° field; multi-coated



The ultimate eyepieces; extreme image sharpness over an amazing 84° field. A perfect optical match with Schmidt-Cassegrains and fast Newtonians.

Ultra Wide Angle (UWA; 8-elements; 1.25°; 84°)—4.7mm: \$169.95 (5.26); 6.7mm: \$199.95 (5.26); 8.8mm (1.25°/2°): \$239.95 (7.02); 14mm (1.25°/2°): \$299.95 (7.02)

Series 4000™ f/6.3 Focal Reducer/Field Flattenor

Manufactured to exclusive Meade optical designs; threads on to any Meade or Celestron Schmidt-Cassegrain rear cell and converts f10 scopes to f6.3 for f6.3 SCT's to f4, while significantly flattening the field. Use with SCT visual or photo accessories. Actual visual field is increased by 56%, for fine wide-field views of star fields and nebulae. In astrophotography, reduces exposure times by about 50%, while producing an actual field diameter of 1.5° at the film plane. A tremendous aid for CCD imagers in reducing image size for locating and centering images on CCD chips. 4-element optics; multi-coated; 41mm clear aperture.



\$129.95 (5.26)

2x Telenegative Barlow (1.25°)

#122: Doubles eyepiece power with sharp, high-resolution, high-contrast imaging on telescopes of all types. 27mm dia. (26mm clear aperture). Excellent corrections for chromatic and spherical aberrations at all photo-visual wavelengths. Multi-coated. 1.25°



\$47.95 (4.54)

2x Short-Focus Barlow (1.25°)

#126: Only 2.5" long the #126 works well with any eyepieces accepting 1.25° eyepieces, even those with limited focus range. Maintains the high image quality of the #122, above. Insert the #126 into star diagonal for 2x or insert star diagonal into #126 for 3x. 26mm clear aperture. Multi-coated.



\$47.95 (4.54)

2x-3x Variable Barlow (1.25°)

#127: Precision internal sliding lens assembly permits continuously variable power settings between 2x and 3x. Engraved scale indicates power in use. Yields bright, sharp, high-contrast images on telescopes of all types. Multi-coated; 1.25°.



\$59.95 (4.54)

2" Diagonal Mirror

#929: Permits use of wide-field 2" oculars. Threads on to rear cell of Meade and Celestron SCT's. Includes multi-coated precision optical flat made at the Meade factory; with 1.25° eyepiece adapter. #930: Same as #929 but with 2" barrel to fit into focuser with 2" eyepiece-holders.



#929 or #930, each: \$99.95 (6.85)

45° Erecting Prisms

Fully coated roof prisms to invert the astronomical image in Schmidt-Cassegrains or reflectors during terrestrial observations, while presenting a convenient 45° observing angle. Specify #927 (.965°), #928 (1.25°), or #931 (fits .965° focuser, accepts 1.25° eyepieces).



\$42.95 (3.86)

World's Most Advanced Illuminated Reticle Eyepiece

Series 4000 Plössl 9mm, with rubber eyecup and micrometric X-Y positioning of the reticle within the field. Greatly facilitates locating the guide star. Sharp high-power imaging, excellent eye relief. Wireless red LED illuminator with adjustable brightness control. Multi-coated optics. Internal batteries included. Bullseye reticle. 1.25°.



\$149.95 (6.14)

Series 4000 Plössl 9mm—Same as above but with 6 ft. cord and plug for Meade LX3, LX3, LX6, LX100, LX200, and APO power panels. In place of wireless illuminator.

\$129.95 (5.26)



Series 4000 Photo-Visual Color Filters (1.25°)—Premium filters, made of purest crown optical glass, dyed in the mass. For increased contrast and resolution on the Moon and planets. Thread into the barrels of virtually all 1.25° eyepieces sold today. Fully coated.

#6 Lt. Yellow; #11 Yellow Green; #12 Yellow; #21 Orange; #23A Lt. Red; #25A Red; #38A Dark Blue; #47 Violet; #56 Lt. Green; #58 Green; #80A Blue; #82A Lt. Blue

each \$14.95 (2.73)

Set #1—4 filters: #12, #23A, #58, #80A \$49.95 (4.54)
Set #2—4 filters: #11, #25A, #47, #82A \$49.95 (4.54)
Set #3—4 filters: #6, #21, #38A, #56 \$49.95 (4.54)

Series 4000 Moon Filter (#ND96): Reduces glare and irradiation during lunar observing. 13% uniform light transmission across the visual spectrum. Threads into 1.25° barrels.

\$16.95 (2.73)

#905 Variable Polarizer (1.25°)

For glare reduction in observing the Moon. Includes two Polarizer filters mounted in a machined cell and permits continuously variable light transmission from 5% to 25%, to compensate for varying lunar surface brightness according to the Moon's phase and the aperture of the telescope. Accepts 1.25° eyepieces.



\$49.95 (5.26)

Electric Focusers for SCT's

For extremely smooth microfocusing of the image. Does not affect use of the manual coarse-focus knob.



#1206 Electric Focuser: Plugs into control panel of Meade 8", 10", 12" LX200 models and operates from LX200 hand controller. (Not for LX200GPS models.)

\$149.95 (7.48)

#1205 Electric Focuser: For all other Meade 8", 10", 12" SCT models; includes separate hand controller; accepts one self-contained (user-supplied) 9v. battery.

\$169.95 (7.88)

#777 Off-Axis Guider for SCT's

Internal prism diverts light for monitoring telescopic image during long-exposure astrophotography. Threads to any Meade or Celestron rear cell. Use with illuminated reticle eyepiece and T-Mount for your 35mm camera.



\$79.95 (6.85)

Series 4000™

2x Apochromatic Barlow Lens

#140: The most advanced Barlow lens available for commercial telescopes, the Meade #140 includes 3-element, multi-coated, air-spaced optics. Doubles the power of any eyepiece with which it is used and yields images absolutely unmatched in resolution, contrast and color correction. The #140 optically complements any telescope—refractor, reflector, or Schmidt-Cassegrain. Accepts 1.25° eyepieces. Mechanical components are of machined aluminum and brass. Lens diameter is 28mm; clear aperture 26mm.



\$79.95 (5.26)

Series 4000™ Super Wide Angle

67° field; multi-coated



For exquisite wide-angle images at low-to-medium powers, with pinpoint edge-of-field resolution. Ideal for star fields, galaxies, and other deep-space phenomena. SWA 13.8mm, 18mm, and 24.5mm are superb complements to the #140 Barlow, above.

Super Wide Angle (SWA; 6-elements; 1.25°; 67°)—13.8mm: \$139.95 (4.54); 18mm: \$149.95 (4.54); 24.5mm: \$179.95 (5.26); 32mm (2°): \$239.95 (7.02); 40mm (2°): \$299.95 (7.02)

Series 3000™ Plössl

50° field; multi-coated



Meade Series 3000 Plössl yield the finest image corrections obtainable from the classical 4-element Plössl design. Focal lengths from 5mm through 25mm are parfocal, so that, at most, only slight refocusing of the image is necessary from eyepiece to eyepiece. Unlike competing moderately-priced Plössl's, Meade Series 3000's are multi-coated for maximum light transmission and image contrast. Chrome-plated brass barrels are threaded for standard filters. All eyepieces are fitted with fold-down rubber eyecups for comfortable observing. The PL40mm (for right in photo), an excellent complement to any ocular set, produces spectacular low-power, wide fields, ideal for scanning the Milky Way. Manufactured exclusively to Meade optical designs, Series 3000 Plössl's yield fine, high-resolution results on reflectors, refractors, and Schmidt-Cassegrains of any focal ratio.

Series 3000 Plössl's (4-elements; 1.25°; 50°)

5, 6.7, 9.5, 16, 25mm each: \$49.95 (3.86); 40mm \$79.95 (3.86)



Series 4000 Nebular Filters—Premium multi-layer interference filters, the finest obtainable. Use broadband ("B") filters to block most forms of light pollution; use narrowband ("N") filters in heavily light-polluted areas or for extremely high-contrast observing of faint nebulae.

#908B—Threads into 1.25° eyepieces, 26mm dia. \$79.95 (4.54)
#910B—Threads into 2° eyepieces, 44mm dia. \$119.95 (5.26)
#911B—Threads on to rear cell of Schmidt-Cassegrain telescopes, 36mm dia. \$99.95 (5.26)
#908N—Threads into 1.25° eyepieces, 26mm dia. \$89.95 (4.54)
#910N—Threads into 2° eyepieces, 44mm dia. \$129.95 (5.26)
#911N—Threads on to rear cell of Schmidt-Cassegrain telescopes, 36mm dia. \$119.95 (5.26)

Series 4000 Oxygen-III Filters—Observe diffuse emission and planetary nebulae as you never thought possible. Exclusive Meade 40-layer interference coating technology isolates the 496nm and 501nm O-III lines to tremendously enhance observable nebular structural detail in all telescopes.
#908X—Threads into 1.25° eyepieces, 26mm dia. \$99.95 (4.54)
#910X—Threads into 2° eyepieces, 44mm dia. \$159.95 (5.26)
#911X—Threads on to rear cell of Schmidt-Cassegrain telescopes, 36mm dia. \$149.95 (5.26)

Vibration Isolation Pads

Designed by Meade engineers, these isolation pads reduce typical telescope-tripod vibration damping times to less than one second. A tremendous aid for both visual and photographic astronomy. Place one pad under each tripod leg. #695 Vibration Isolation Pads, per set of three.



\$49.95 (6.85)

MA12mm Illuminated Reticle Eyepiece

Excellent 3-element optical system, long eye relief, fully coated, with double crosshairs reticle; rubber eyecup. Wireless red LED illuminator and variable brightness control. 1.25°. Batteries included.



\$99.95 (3.45)

As above but with 6 ft. cord and plug for Meade telescopes with power panels, in place of wireless illuminator.

\$79.95 (5.26)

Camera Adapters

Professional-quality adapters for rigid coupling of telescope-to-camera. Use for either Eyepiece-Projection or Prime Focus. Precision-machined of aluminum and brass, threaded for filters. Use with T-mount, available separately.



.965°: \$27.95; 1.25°: \$29.95 (3.86)

Variable-Projection Camera Adapter (1.25°)

Machined sliding cell allows variable projection in eyepiece-projection photography; permits precise selection of correct photo power in lunar and planetary photography; threaded for filters. Use with T-mount for your camera.



\$39.95 (3.86)

Variable Tele-Extender

For eyepiece-projection photography with any Meade or Celestron SCT. Threads on to eyepiece-holder. Sliding cell with lock permits wide range of projection magnifications with the same eyepiece. Use with T-mount for your camera.



\$39.95 (3.86)

T-Adapters for SCT's

Rigidly couples camera to telescope for prime focus photography with any Meade or Celestron Schmidt-Cassegrain. Use with T-Mount for your 35mm camera.



\$26.95 (3.86)

CCD-Photo-Visual Flip-Mirror Systems

An essential accessory for imaging with any brand of CCD imager or for astrophotography with a 35mm camera. Flip mirror "down" to center the image while viewing with an eyepiece at 90°; flip mirror "up" to pass light on to CCD chip or 35mm camera film plane. Each unit includes: precision optical-flat Pyrex® mirror; 2-axis mirror-adjustment screws and locks for precise image centering; extra-fine helicoid focusing of the eyepiece; extension tubes for attaching either 35mm camera (using T-Mount) or CCD imager (using either T-threads or 1.25" barrel). Threads to rear cells of all Schmidt-Cassegrain telescopes; may remain on telescope and used in place of diagonal prism for visual observing as well.

"Over the past 10 years I have used all manner of flip-mirrors. The Meade Flip-Mirror Systems are absolutely the best—rock solid, high-precision, beautifully manufactured; they virtually eliminate all flexure between the CCD and telescope." — Jack Newton



#644 Flip-Mirror System: Accepts any 1.25" eyepiece. Mirror clear aperture: 22mm. Use with CCD's up to Pictor 416XT or ST-7, or smaller; or visual observing with 1.25" eyepieces.

\$149.95 (7.02)

#647 Flip-Mirror System: Accepts either 1.25" or 2" eyepieces. Mirror clear aperture: 40mm. Recommended for full-field 35mm astrophotography or with CCD's of any size, including all Meade Pictor Series through 1616XT, as well as ST-4 through ST-10; or for visual applications with 1.25" or 2" eyepieces.

249.95 (8.49)

#157 1.25" Adapter: Permits use of either Flip-Mirror on telescopes with 1.25" eyepiece-holders. (Requires approx. 2" additional focus travel with #644, 3" with #647.)

15.00 (3.86)



**Series 4000™
f/3.3 CCD Focal
Reducer/Field
Flattener**

Revolutionary 3-element Meade design permits ultrafast CCD imaging with increased edge-of-field resolution and color correction! Reduces CCD exposure times by up to 80%. Threads on to the rear cell of any Meade or Celestron f/6.3 SCT's to f/7. Variable T-Adapter (included) allows range of fit between f/3 and f/5 on f/10 SCT's and between f/1 and f/2 on f/6.3 SCT's. Use with CCD imagers of any brand and chip dimensions. Not for visual or photographic applications. Multi-coated, 41mm clear aperture.

\$149.95 (5.26)

**Plossl 25mm Illuminated Reticle
CCD Framing Ocular**

Displays rectangular frames of all popular CCD chip sizes, including all Meade Pictor models and ST-4 through ST-8. Shows precisely the image size and orientation that appear on CCD chip. Insert directly into telescope eyepiece-holder, or use with Flip-Mirror (above). Includes 4-element coated Plossl optics; lockable spacer ring to fix focus position; rubber eyepiece; variable LED illumination control; batteries, 1.25".

\$129.95 (4.54)

**#825 8 x 25mm
Right-Angle Viewfinder
for ETX-90**

Permits comfortable right-angle viewing. Replaces standard eyepiece on 90mm ETX models using the same bracket. Wide-angle, achromatic coated optics; actual field 7.5°. Precise helicoid focusing.

\$49.95 (4.26)

#64 T-Adapter for ETX®

Threads to photo port of all ETX-90, ETX-105, and ETX-125 models. Rigidly couples any 35mm camera with removable lens to the telescope for lunar, planetary, or terrestrial photography. Includes extension tube for longer effective focal length, if desired. Use with T-Mount for your 35mm camera.

\$34.95 (3.86)

**MA12mm Illuminated Reticle
Astrometric Eyepiece**

A high-precision eyepiece for a wide range of astronomical measurements. Includes four red-illuminated, laser-etched scales for measuring double star angular separations, position angles, planetary diameters, and lunar crater diameters; and for long-exposure photo-guiding. Modified Achromatic, 3-element coated optics; diopter adjustment; rubber eyepiece; variable LED illumination control; batteries, 1.25".

\$119.95 (4.26)

**Series 4000™
8mm – 24mm
Zoom Eyepiece**

The finest zoom eyepiece available. High-resolution 7-element multi-coated optics, with 55° field at 8mm. Graduated scale in 1mm units indicates exact focal length in use. High-eyepoint yields comfortable observing even with eyeglasses. Internal zoom lenses move on the smoothest, most precisely-machined tracks yet developed for zoom optics. Performance is fully consistent with the finest fixed-focal length eyepieces. Threaded for filters; rubber eyepiece, 1.25".

\$219.95 (6.38)

**ETX® Hard
Carrying Cases**

For secure storage or travel with your ETX. Thick-wall construction and die-cut foam lining. Accepts telescope, optional eyepieces, erecting prism, table tripod, hand controller, etc. Includes steel latches & key.

- #774 Case for ETX-90 models: **99.95 (5.58)**
- #776 Case for ETX-105EC: **99.95 (5.58)**
- #775 Case for ETX-125EC: **149.95 (13.38)**

Dew Shields for ETX®

Threads into the front-lens cell and effectively inhibits the formation of dew on the lens surface.

- #670 for ETX-60/70: **19.95**
- #673 for ETX-90: **24.95**
- #675 for ETX-105: **27.95**
- #678 for ETX-125: **29.95**

**Advanced Field Tripod
for ETX-125**

#887: Yields rock-solid stability for sensitive applications of the ETX-125, even at high magnifications. Includes fixed-height tripod convenient for standing observations, equatorial wedge with alignment controls in azimuth and latitude angle, and **#889 Tripod Adapter for ETX-125.** Permits either alt-azimuth or equatorial orientation of the telescope for astronomical or terrestrial observing. Tripod legs are 2" diameter chromed steel. For field use the tripod collapses for easy transport.

\$349.95 (14.00)

**Tripod Adapter
for ETX-125**

Included with the #887 Tripod (above), the #889 Adapter is available separately and permits attachment of ETX-125 directly to any Meade LX10, LX50, or LX200 Schmidt-Cassegrain Field Tripod for alt-azimuth observing or to any Meade Schmidt-Cassegrain Tripod-with-Equatorial Wedge or Superwedge for equatorial applications.

#889 Adapter: \$69.95 (7.70)

**ETX® Deluxe
Field Tripod**

#884: Constructed of strong, lightweight steel; designed specifically for ETX-90, ETX-105, and ETX-125 Astro Telescopes. Tripod height adjusts from 25" to 43", for seated or standing observations. Graduated scale for elevation angle from 20° to 90° permits precise polar alignment of the telescope for astronomical applications. Tripod fits and locks at 90° for terrestrial applications or for alt-azimuth use with Austar. Telescope attaches to tripod in seconds with 2 thumbscrews. Includes custom-fitted carry bag (shown) with pocket for accessories.

\$199.95 (10.00)

ETX® Carry Bag

Soft-padded Cordura-type carry bag, with shoulder strap; permits storage of any 90mm ETX model plus table tripod, legs, eyepieces, other accessories.

\$36.95 (5.26)

**Electric
Focuser
for ETX®**

Meade-engineered for smooth, rapid focusing with ETX-90, -105, or -125. Four-speed operation from coarse to microfine. Standard equipment hand-controller accepts one 9v (user-supplied) battery and focuses all ETX telescopes. Or focus through the telescope's Electronic Controller (EC) or through Autostar.

#1244 Electric Focuser for all ETX-90 and ETX-105 models: \$119.95 (6.85)

#1247 Electric Focuser for ETX-125 models: \$119.95 (6.85)

HOW TO ORDER

Prices shown are suggested U.S.A. mail-order retail prices and do not include any applicable sales taxes. Suggested shipping and handling charges to the 48 states by U.P.S. or U.S. Mail shown in () next to each price. The following national mail-order dealers carry all Meade accessories in-stock for immediate shipment:

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FOCUS CAMERA, Brooklyn, NY.
Orders: 800-221-0828; Info.: 718-436-6262.

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Orders: 800-767-9576; Info.: 925-447-9570.

OCEANSIDE PHOTO & TELESCOPE, Oceanside, CA.
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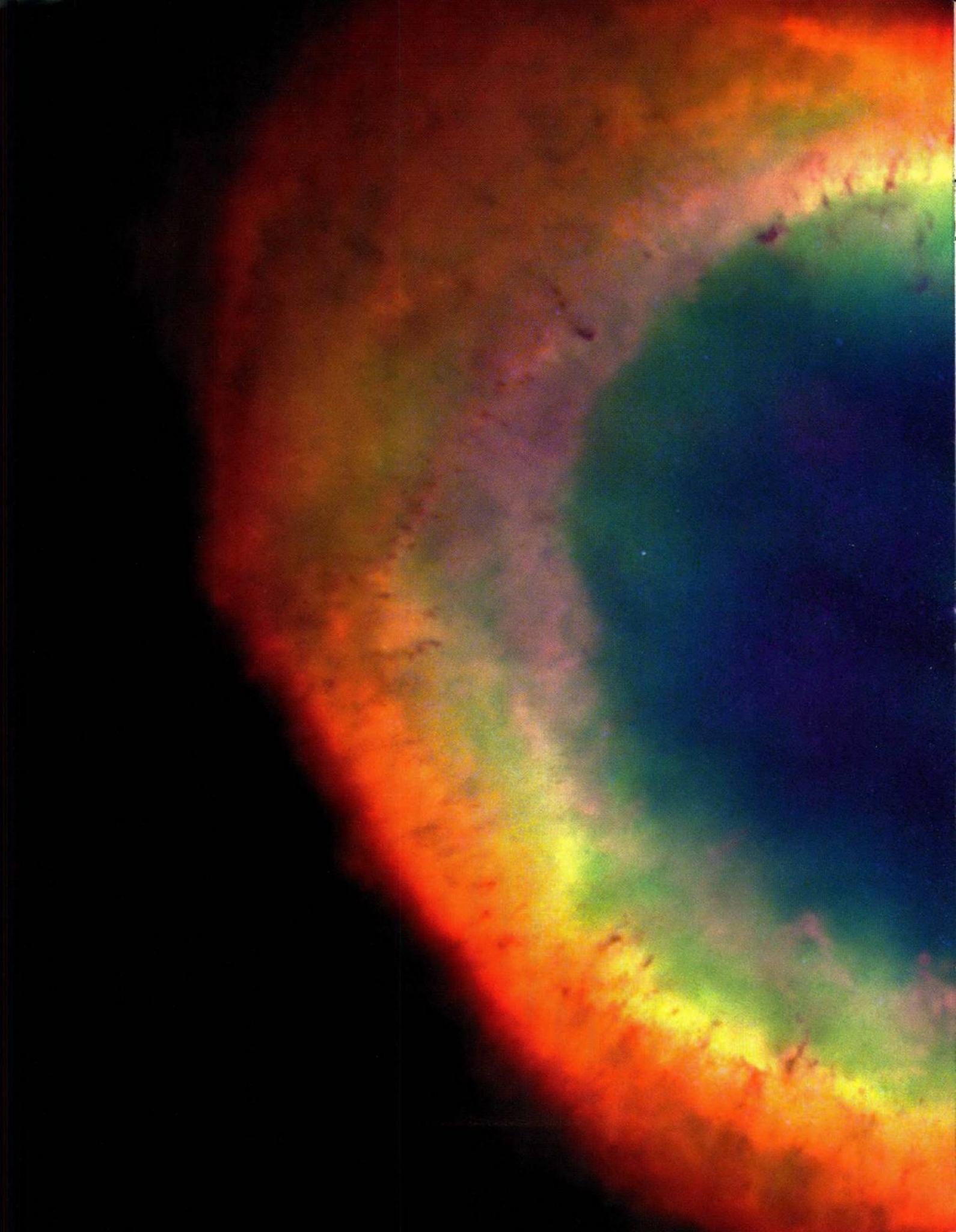
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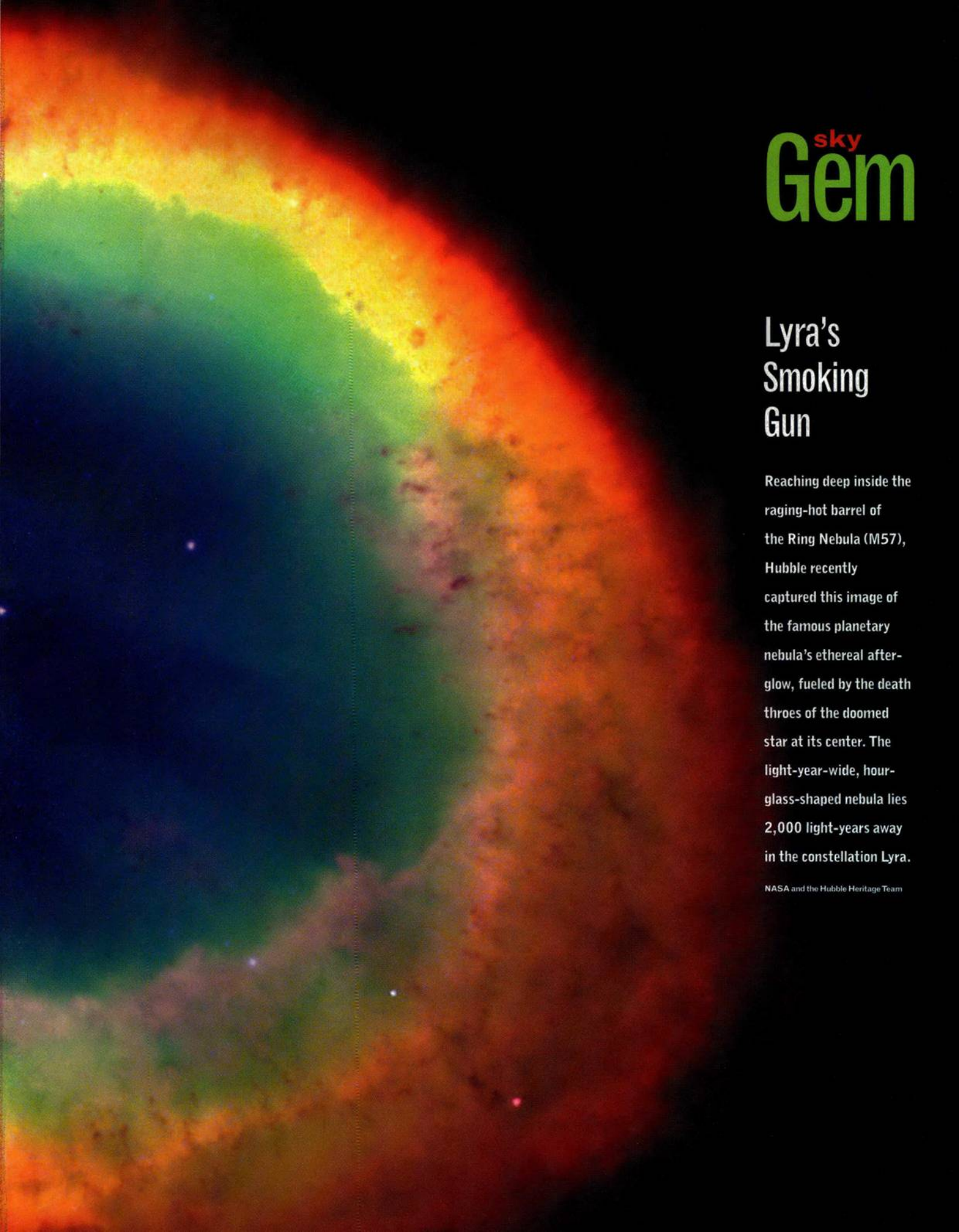
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sky Gem

Lyra's Smoking Gun

Reaching deep inside the raging-hot barrel of the Ring Nebula (M57), Hubble recently captured this image of the famous planetary nebula's ethereal afterglow, fueled by the death throes of the doomed star at its center. The light-year-wide, hour-glass-shaped nebula lies 2,000 light-years away in the constellation Lyra.

NASA and the Hubble Heritage Team

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Black Hole Debate



I think Bob Berman missed an important point in his article questioning the existence of black holes (Strange

Universe, December 2001). The Uncertainty Principle of quantum physics states that if we know the momentum of a particle very precisely, we can't know its position. If an infalling object is stuck at the event horizon and not moving, we don't know where it is. If Hawking Radiation can quantumly tunnel out of a black hole, then objects of near zero momentum can also find themselves inside the event horizon, thus creating a true black hole in a cosmologically short period of time. — Wayne Wyrick, Oklahoma City, Oklahoma

Distinguished astronomers (such as Alex Fillipenko) have had no objections with the reasoning in this article. But to help clarify, I asked relativity expert Tarun Biswas, whom I had quoted in the piece, to comment. He says, "This is a wrong application of the Uncertainty Principle. By this type of reasoning, I can argue that I have no idea where my house is because it is basically stationary and hence has no momentum. A direct application of this principle is valid only for particles with no internal structures (and close approximations thereof). As for Hawking Radiation, its application here is dubious; the theory for it is still just a half-baked quantum gravity, and a consistent theory of quantum gravity still eludes us." — Bob Berman

I believe that Bob Berman's description of black holes is not correct. It is not true that "event horizons have never formed and never will." And one cannot view a black hole as "a thin membrane of dense material that hovers just above an event horizon." Matter falls through the event horizon and disappears from view in finite time. We can only say that it disappears in a whisper, because at the moment of



Objects such as Orion's Belt are featured in **Astronomy 101**. Gianni Tumino and Jean-Marc Lechopier

crossing the event horizon its signals are infinitely red shifted. (Periodic orbits exist around a black hole but those are unstable.) — Jan Mycielski, Boulder, Colorado

The main point stressed in the article is that whatever the density profile may be within the frozen star, the time taken for anything to fall into it will be infinite as seen from any point outside. Since we are thankfully outside, matter (including that which might help create the event horizon to begin with) does not fall through in finite time from our perspective, and in our time frame. It takes infinitely long — and an infinity of time has not yet elapsed, and never will. — Bob Berman

Kudos to Astronomy

I clipped your photo of Orion in **Astronomy 101** (January 2002) to show my three-year-old daughter, who is fascinated by the stars. The bright blue of Rigel and red of Betelgeuse in the photo will help her to understand. I have also customized your page by adding fine print with information such as the magnitudes, light-year distances from Earth, and surface temperatures. She can interpret those when she is ready. Meanwhile, we look forward to your next target. — Joe Hickey, Vallejo, California

I am very impressed with the **Astronomy 101** section. I took an astronomy class, but there is still much I can learn. — Sharon Ann Clark, Kirkland, Washington

Thank you for **Astronomy 101** and **The Savvy Astronomer**! I have been looking for a magazine that offers a monthly guide to learning the sky; it looks like I've already found it. — Michael Bystrowski, Sterling, Virginia

Kilometers Squared?

In "Target Earth" (February 2002), David Morrison states that 600 square miles is equal to about 1,000 square kilometers; the correct figure is 1,554 square kilometers. — Jeffrey Felton, Mt. Baldy, California

Corrections

A photo appearing on page 64 of the February 2002 issue was incorrectly described as the Miami skyline. The photo shows San Diego Harbor. — Astronomy editors

The caption under Jerry Lodriguss's photo of Comet Hale-Bopp (February 2002, page 90) incorrectly describes it as a composite image. The photo is actually a single 5-minute exposure. — Astronomy editors

Randall Wehler's photo on page 110 of the February 2002 issue was incorrectly labeled "Conjunction of the Moon and Mars." The photo shows the moon with Jupiter and Saturn. — Astronomy editors **A**

Astronomy invites you to talk back. Send letters to Astronomy Talking Back, P.O. Box 1612, Waukesha, WI 53187; e-mail to talking@astronomy.com. Letters may be edited for space and clarity. Please include your city, state, and country with all correspondence. If you want to talk back to us, please visit our website, <http://www.astronomy.com>.

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STAR FORMATION

Astronomers Uncover Early Star Boom

► Gorging themselves on the primordial stuffing of the universe, the first generation of stars arrived on the scene like a raging wildfire thirsty for kindling. Long before the giant elliptical and spiral galaxies that dominate the universe today were more than a glimmer in the cosmic eye, starbursting protogalaxies dominated the landscape with supernovae popping like machine-gun fire in every direction and gale-force stellar winds setting off a chain-reaction of star formation. And in the absence of muting effects caused by cosmic dust — the eventual offspring of this premiere generation — only two modes of brightness existed — inky darkness and blinding brilliance.

This new view of the beginning, according to the latest glimpse of the infant universe to be gathered by astronomers using the NASA/ESA Hubble Space Telescope, is causing quite a controversy.

Astronomers have long understood that the crucial, life-sustaining processes of star formation must have begun sometime between the Big Bang and present epoch. The catch is, they seemed pretty sure — after using Hubble to peer deep into the past and generate the Hubble Deep Field North in 1995 and its southern counterpart in 1998 — that the universe underwent a massive “baby boom” when it was about half its present age, or roughly seven billion years ago.



Adolf Schaller for STScI

Not so, says Kenneth M. Lanzetta, an astronomer at the State University of New York–Stony Brook.

According to new research on galaxies residing in both Hubble Deep Fields, Lanzetta and his colleagues have found evidence that the “baby boom” took place almost instantaneously, just a few hundred million years, after the Big Bang. Lanzetta’s conclusions, published in the *Astrophysical Journal*, rely heavily on a few key assumptions and remain to be proven.

A concept that Lanzetta refers to as “missing light” forms the cornerstone for his arguments. By carefully examining the color of starlight from galaxies in the deep fields (the youngest

and most distant galaxies known) Lanzetta and his team have ascertained that rather than representing the cumulative light from an entire galaxy, the light observed in deep-field galaxies is generated only by the biggest and brightest stars and clusters.

In other words, a significant fraction of each galaxy’s light is not represented because it is too dim to be gathered, even by the most powerful telescopes.

According to Lanzetta, astronomers may only be capable of seeing the “tip of the iceberg” when it comes to light from the most distant galaxies, much in the same way tourists on safari can spot only the largest members in a distant herd

Primeval starburst galaxies dominate an artist’s rendering of our baby universe, just a few hundred million years old.

of elephants. To bolster confidence in their results, Lanzetta and his team plan to gather more data with Hubble’s new Advanced Camera for Surveys. In addition, they plan to use supernovae, which don’t dim with distance the same way that galaxies do, as a control for their observations.

If Lanzetta and his colleagues prove to be correct, astronomers will have to tweak their theories to account for a much earlier ignition of the star formation process that continues today, albeit now at a much slower rate. — W. B. SCHOMAKER

COSMOLOGY

Galaxy Shares Dark Secrets

► A recently completed study of the Milky Way Galaxy's helium-3 abundance bolsters the belief that most of the universe is made up of something other than ordinary baryonic matter — matter containing protons and neutrons.

Created moments after the Big Bang and once thought to be continually produced inside sun-like stars, helium-3 (a helium isotope containing a lone neutron and two protons) is of interest to astronomers studying stellar evolution and chemical synthesis in the universe.

For more than two decades, astronomers used the 140-foot (43-meter) radio telescope in Green Bank, West Virginia, to survey the amount of helium-3 in our galaxy. Wherever they peered, whether in regions of sparse or dense star formation, lonely edges, or the

The Milky Way, seen here in infrared light, may hold keys to the origins of matter.

vivacious heart of our galaxy, the team found almost identical trace amounts of helium-3.

"If stars were indeed producing helium-3, as scientists believed, then we should have detected this element in much greater concentrations," says team member Robert Rood, a University of Virginia astronomer who has scanned the Milky Way for helium-3 since 1978. The observations led Rood to suspect that stars produce negligible amounts of helium-3, as his team reported in the January 3 issue of *Nature*. Moreover, they believe that the unwavering abundance they've observed is likely that of primordial helium-3 generated by the Big Bang.

The astronomers also measured the amount of hydrogen wherever they observed helium-3. The ratio of the isotope to hydrogen helped the team calculate an upper limit for the amount of baryonic matter created by the Big Bang. Their findings corroborate earlier reports that much of the universe is made of matter unlike anything seen on Earth.

— VANESSA THOMAS

RADAR ASTRONOMY

Arecibo NEO Studies Proceed

► Astronomers and the public alike can rest assured knowing that radar tracking of Near Earth Objects (NEOs) will continue at the Arecibo Radio Observatory in Puerto Rico.

Late last year, NASA announced plans to discontinue the program at the start of 2002 because of mounting budget constraints generated by a U.S. Congressional mandate to identify all NEOs larger than 1 kilometer (0.6 miles) across by 2008. Currently, the large Arecibo radio dish remains the only facility capable of tracking the orbits of NEOs and characterizing their potential to threaten Earth.

Fueled largely by sharp criticism from the Division of Planetary Sciences of the American Astronomical Society and the Planetary Society, NASA agreed to reconsider its plans to let radar tracking "take a back seat" to the search for new NEOs. Planetary Society executive director Louis



S. Ostro/JPL

NASA has pledged to continue nominal funding for NEO tracking studies with the 1000-foot (305-meter) radio telescope in Arecibo.

Friedman spoke harshly against NASA's original plan. "The decision to eliminate these Arecibo observations, and not obtain precision data, is very short-sighted. If an object is discovered heading toward Earth, we are certainly going to wish that we had the ability to track it accurately," he says.

NASA has committed to reinstate \$400,000 for F.Y. 2002, in order to cover operations and planning costs. Moreover, NASA officials have initiated efforts to secure additional funding for the program from the National Science Foundation. — W. B. S.

CHANDRA OBSERVATORY

X-Ray Glimpse of Galaxy Core

► As astronomers peer into the universe, they see exploding stars, blazing quasars, colliding galaxies, and a wealth of other violent events.

The relatively tranquil backwaters of the Milky Way Galaxy seem a welcome respite from the



2MASS



helter-skelter cosmos, particularly for those who appreciate the conditions necessary for advanced life.

Yet looks can be deceiving, particularly when faced with the parochial view offered by visible light. By expanding our vision to other wavelengths, the true nature of our galaxy comes to light — and it's not the peaceful place that it at first appears to be.

Astronomer Q. Daniel Wang of the University of Massachusetts–Amherst and his colleagues pointed the Chandra X-ray Observatory toward the center of the Milky Way and made a stunning panorama of its high-energy emission.

“The center of the galaxy is where the action is,” explains Wang, who released the observations at the January 2002 meeting of the American Astronomical Society in Washington, D.C. “With these images, we get a new perspective on the interplay among stars, gas, and dust as well as the magnetic fields and gravity in the region.”

The Milky Way's supermassive black hole lies somewhere beneath the central swarm of this Chandra x-ray image. Sharing the spotlight are tons of glowing gas and hundreds of white dwarfs, neutron stars, and black holes.

The panorama consists of 30 separate Chandra images covering a combined 400- by 900-light-year swath. More than 94 hours of observing time went into making this first wide-field, high-resolution x-ray image of the Milky Way's core.

The sharp detail helped the astronomers resolve more than 1,000 individual x-ray sources. “We can now see that these sources are responsible for most of the x rays previously attributed to the diffuse glow produced by hot gas,” says team member Eric Gotthelf of Columbia University. Spectra suggest that the sources are white dwarfs, neutron stars, and black holes accreting matter.

The galaxy's center still shows a diffuse glow; the gas creating it just isn't as hot as previously thought. Although few would argue that a temperature of nearly 20 million degrees qualifies as tepid, it's downright chilly compared with earlier estimates approaching 200 million degrees.

The diffuse emission seems to be related to the formation of massive stars, which occurs at a much faster rate near the galactic center than in the suburbs where the sun lies. These stars boil off their outer layers in searing stellar

HUBBLE SPACE TELESCOPE



NASA/ESA and the Hubble Heritage Team

LIKE TORCHLIGHT BENDING in a steady breeze, glowing gas from the Hubble-V nebula in the nearby galaxy NGC 6822 reveals the latent power of newly formed stars. A dense group of infant (4-million-year-old) stars at the eastern edge (lower right) of the star-forming nebula burn with the brightness of several million suns. Consequently, their emerging light energizes the nearby nebular material, causing it to fluoresce. Astronomers using the NASA/ESA Hubble Space Telescope captured this three-and-a-half-hour exposure of the 200-light-year-wide nebula in 1996. Lying just 1.6 million light-years away, NGC 6822 is one of the Milky Way Galaxy's nearest neighbors.

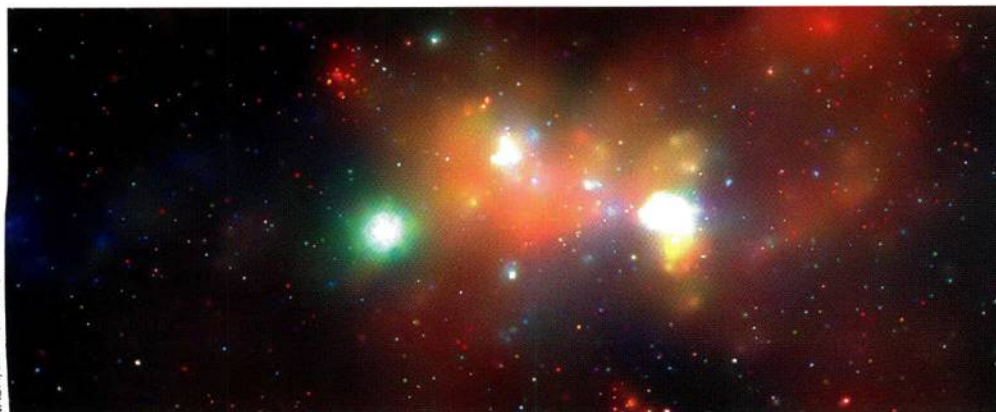
winds that combine with the debris from supernova explosions to permeate the inner galaxy. The hot gas appears to be escaping from the center into the rest of the galaxy, enriching it in heavy elements. — RICHARD TALCOTT

COSMOLOGY

Neutrinos Kink Cosmology

► If a 45-member collaboration of American physicists proves correct, scientists may soon have to go back to the drawing board to develop a new standard model of physics that includes extra forces, particles, or dimensions above and beyond those already accounted for.

According to a report published in the journal *Physical Review Letters*, the team began suspecting problems with the current



NASA/JPL/UMass/D. Wang



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model when neutrinos (fundamental particles that carry no charge and only interact with matter via the intra-atomic weak force) generated in the lab didn't behave as predicted.

With the Tevatron accelerator (the world's most energetic particle accelerator) at the Fermi National Accelerator Laboratory in Batavia, Illinois, the team generated billions of neutrinos with a 100-million-watt proton-beam, slammed them into a series of target nuclei, and observed the aftermath.

According to theory, when neutrinos would strike a target nucleus, they could either pass on through or turn into a muon, a heavier cousin of the electron. To its surprise, the team found a one

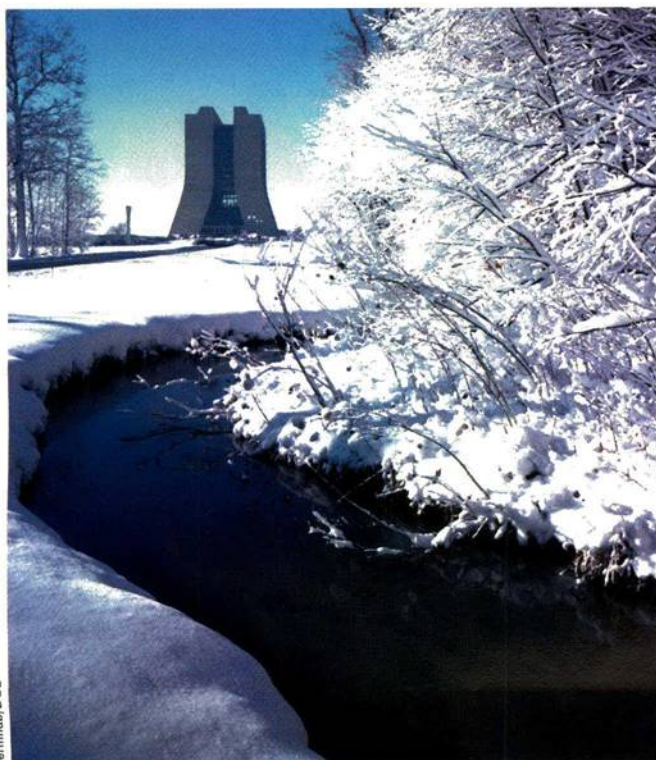
Physicists at the Fermi National Accelerator Laboratory blast atoms with proton-beams to unlock the secrets of the universe.

percent discrepancy between the results and the theoretical predictions.

"It might not sound like much," says Northwestern University graduate student Sam Zeller, "but a room full of physicists fell silent when we first revealed the result."

The team spent a year evaluating its data and eventually reached the conclusion that the neutrinos acted according to prediction in only one out of every 400 trials. The team isn't absolutely sure how to explain the discrepancy, but the behavior could be explained by unknown particles or forces that are altering the expected neutrino interactions.

Around the world, physicists are developing future accelerator experiments that will be capable of solving this riddle for good. In the meantime, others are using accelerators to search for evidence of missing particles and forces. — W. B. S.



Fermilab/DOE

VERY LARGE TELESCOPE



ESO/VLT

BEYOND THE VEIL of light-obscuring dust, young, massive stars have been roused from hiding in the Eagle Nebula (M16). Made famous by the NASA/ESA Hubble Space Telescope in 1995, these so-called "Pillars of Creation" have recently been probed for their infrared light by the Very Large Telescope (VLT) 8.2-meter Antu telescope at ESO's Paranal Observatory in Chile. In keeping with earlier Hubble observations, astronomers find that the pillars are sculpted and illuminated by light from a nearby cluster of stars called NGC 6611. But the infrared investigation also reveals something new — young, massive stars nestled in the pillars themselves. Astronomers discovered these new heavyweight stars, whose formation may have been sparked by the steady onslaught of radiation from NGC 6611, near the tips of at least two of the Eagle's pillars.

EARTHSHINE

Moon Reflects Pulse of Life

▶ In a classic moment of self-reflection aimed toward discovering Mother Earth's distant, extrasolar cousins, astronomers have begun to take a long, hard look at our

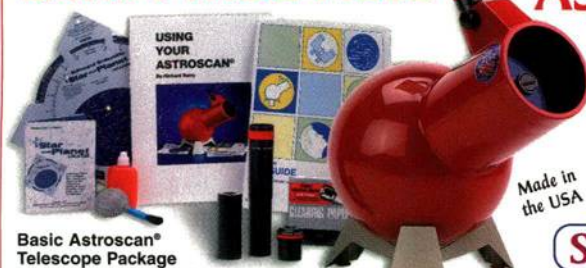
planet through a nearby celestial mirror — the moon.

University of Arizona astronomers Nick Woolf and Paul Smith recently reported — at this year's winter meeting of the American Astronomical Society in Washington, D.C. — that "earthshine" can provide a unique glimpse of our famously habitable biosphere.

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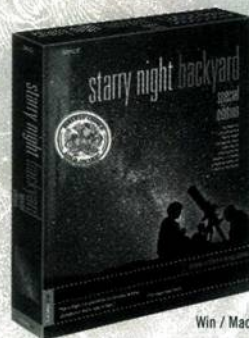
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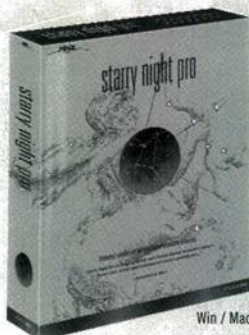


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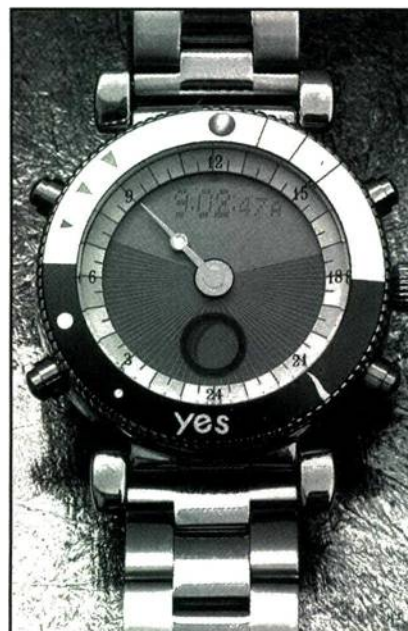
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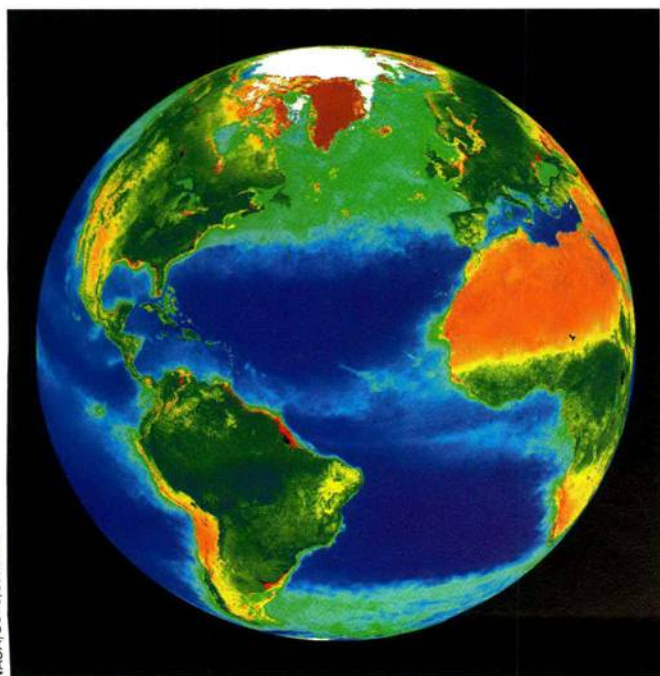
Earthshine lights up the otherwise dark region of the crescent moon as sunlight reflects back into space from Earth's surface, onto the lunar surface, and then back again. Other space scientists have recently exploited this "ashen light" as an indirect means of tracking global climatic changes.

Wes Traub and Ken Jucks from the Harvard-Smithsonian Center for Astrophysics have also recently used earthshine to model the theoretical spectrum of our living world.

But Woolf and Smith's work marks the first occasion in which scientists have obtained a complete spectrum of light reflected by the entire globe.

If astronomers didn't have the benefit of earthshine, says Woolf, they would require a special spacecraft to capture Earth's reflected spectrum. Current

Scientists are looking to the moon, rather than satellite data like this SeaWiFS image, to study Earth's life-bearing characteristics.



HUBBLE SPACE TELESCOPE



THE MAGNIFICENT STAR-FORMING NEBULA IC 2944 lies just 5,900 light-years from Earth. A newly released NASA/ESA Hubble Space Telescope image of a small region near the heart of IC 2944, amid the nebula's youngest and brightest (O-type) stars, displays a closeup view of several curious dark blobs called Thackeray's Globules. Named after A. D. Thackeray, who

discovered them in 1950, the dense globules appear dark because they completely block incoming starlight from behind. The gas in these globules, which might have produced as many as 15 stars like the sun if it had remained shielded from the ultraviolet sandblasting of nearby stars, will eventually heat up and dissipate into the surrounding nebula.

spacecraft are great for getting specific, detailed views of Earth and its varied habitats, but are woefully

inadequate at judging overall earthly character.

Last summer, Woolf and Smith used the Steward Observatory's 90-inch (229-cm) telescope atop Kitt Peak to observe the earthshine spectrum. The pair corrected the spectrum for such factors as lunar reflection, solar radiation, and an extra pass of light through Earth's atmosphere by dividing the earthshine spectrum by that of the sunlit moon. In so doing, they obtained a spectrum that is identical to what could be obtained from space.

Woolf and Smith were also able to discern spectral features generated by the presence of water vapor, molecular hydrogen, and ozone in the upper atmosphere, among others.

"There were also broad features," says Woolf. "We

saw the blue of the sky, caused by the molecules of air-scattering sunlight. This measures the amount of atmosphere on Earth. Also, there is an abrupt rise in the spectrum in the far red, where vegetation is strongly reflective. This was quite surprising to us because only 17 percent of the illuminated area of Earth was of land. Sea vegetation is not able to produce this signature because seawater strongly absorbs the light of this color."

The University of Arizona team's work seems timely and auspicious now that astronomers have recently managed to obtain the first spectral signatures of a distant exoplanet's atmosphere (see "Astronomers Probe Alien Skies," *Astronews* March 2002.)

— PAUL MORLEDGE

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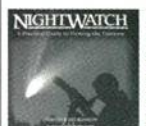
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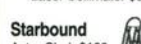
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DARK MATTER

Mapping Dark Matter

► Astronomers have come a few steps closer to cracking the mystery behind the elusive dark matter that dominates the universe. With data from the Australian/British 2dF Galaxy Redshift Survey, researchers have found that on large scales, dark matter is distributed just like galaxies.

Attempting to map the distribution of dark matter with a telescope is a bit like locating the trunk and branches of a Christmas tree at night; the bright lights are visible, but not the whole tree. But now, using new statistical analysis techniques and distant microwave observations, a team of 30 astronomers has pinned down where the dark matter is located.

One study, led by Ofer Lahav and Sarah Bridle of Cambridge University, contrasted fluctuations in the 2dF galaxy distribution with

that of the Cosmic Microwave Background (CMB) — radiation left over from the Big Bang. “Small density fluctuations, produced shortly after the Big Bang, are expected to be the seeds that grow, due to the force of gravity, to become present-day galaxies,” explains Bridle.

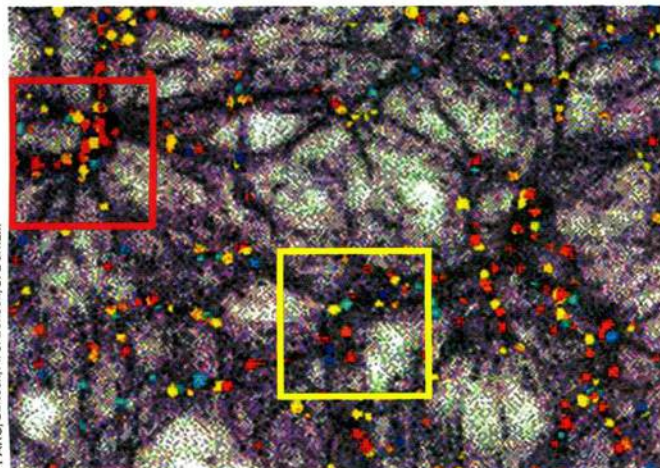
A second study, led by Alan Heavens of the University of Edinburgh and Licia Verde of Rutgers University, has discovered that dark matter and visible galaxies generally stick together, forming vast voids, sheets, and filaments.

“For twenty years, astronomers have debated whether galaxies trace out the dark matter,” says Heavens. “This [affirmative] result will place strong constraints on theories of where and how galaxies form.”

The discovery also led Heavens’ team to find that about seven times as much dark matter exists than ordinary matter, still only about one quarter of the matter needed to bring the expansion of the universe to a halt. — ELESJA JANKE

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Dark matter (gray background) and galaxies (colored dots) mirror alternating patterns of clustering (red box) and voids (yellow box).



PPARC/Callech/A. J. Benson/U. Durham

Astronomers Consider Dark-Side Move

In search of some well-needed peace and quiet, radio astronomers are starting to seriously consider packing up and taking their business elsewhere — to the dark side of the moon. Errant radio noise, unleashed by the present swarm of communications satellites orbiting Earth, is taking its toll on radio observations of the universe.

Italian astronomer Claudio Maccone, for one, is an advocate for astronomers taking back control of a deteriorating situation and constructing a radio observatory on the moon’s shielded side. In addition to filtering radio noise from earthly emissions, placing a radio scope on the moon will expand astronomers’ coverage of the radio spectrum by allowing them to gather wavelengths otherwise absorbed by Earth’s atmosphere.

Close Call for Planet Earth?

An asteroid large enough to knock out a medium-sized nation like France surprised astronomers as it whooshed by uncomfortably close to Earth on January 7. The wandering space rock, dubbed asteroid 2001 YB5 — estimated to be a little wider than three football fields (300 meters) in diameter — passed by Earth at a little more than two times the moon’s distance, or about 510,000 miles (830,000 km) away. Discovered only in early December 2001, YB5 was observed and tracked beginning January 5, 2002, by astronomers at the Klet Observatory in the Czech Republic.

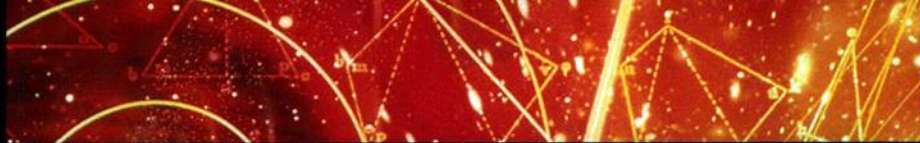


A wandering asteroid could deal a devastating blow to Earth.

Kids Do Science with Spacey Disco Balls

Two spacefaring, mirror-encrusted, aluminum spheres dubbed STARSHINE 2 and STARSHINE 3 are giving hundreds of students on the ground their first experience with science. Project STARSHINE (short for Student-Tracked Atmospheric Research Satellite for Heuristic International Networking Experiment) is an ambitious volunteer effort, combining forces between NASA, the United States Naval Research Laboratory, the Space Grant Program, and over 30,000 children from 660 schools in 26 countries around the world.

According to project director Gil Moore, a retired aerospace engineer from Monument, Colorado, the aim of the program is to monitor the orbiting beach-ball-sized disco balls, which regularly pulse with reflected sunlight as they spin, to measure the thickness of Earth’s atmosphere and its dependence on solar cycles. If you are interested in lending your eyes to the project, visit www.azinet.com/starshine/. Like their predecessor STARSHINE 1, which burned up on reentry in February 2000, STARSHINE 2 and STARSHINE 3, will return to Earth in 2002 and 2004, respectively.



INFLATION. WHAT'S IT ALL ABOUT, ANYWAY? MORE A PRESCRIPTION FOR FINE-TUNING OUR UNDERSTANDING OF THE BIG BANG THAN A FULL-FLEDGED THEORY ITSELF, THE IDEA — FIRST REVEALED BY RUSSIAN PHYSICISTS, BUT ULTIMATELY CHRISTENED THE 1979 BRAINCHILD OF A THEN-UNKNOWN STANFORD POSTDOC NAMED ALAN GUTH — HAS ESTABLISHED ITSELF IN THE LAST 23 YEARS AS A PANACEA FOR A LONG LIST OF CHRONIC COSMOLOGICAL CONCERNS. AS YOU'LL DISCOVER IN THE FOLLOWING PAGES, INFLATION ADEPTLY EXPLAINS WHY THE UNIVERSE IS SO LARGE, HOMOGENOUS, AND UNIFORM IN EVERY DIRECTION, AS WELL AS HOW THE STUFF THAT MAKES UP OUR UNIVERSE CAME TO BE. BE SURE TO VISIT ASTRONOMY.COM TO READ MORE ABOUT WHY THE BIG BANG MODEL REQUIRED FINE-TUNING, AND TO MEET THE PERSONALITIES BEHIND INFLATION.





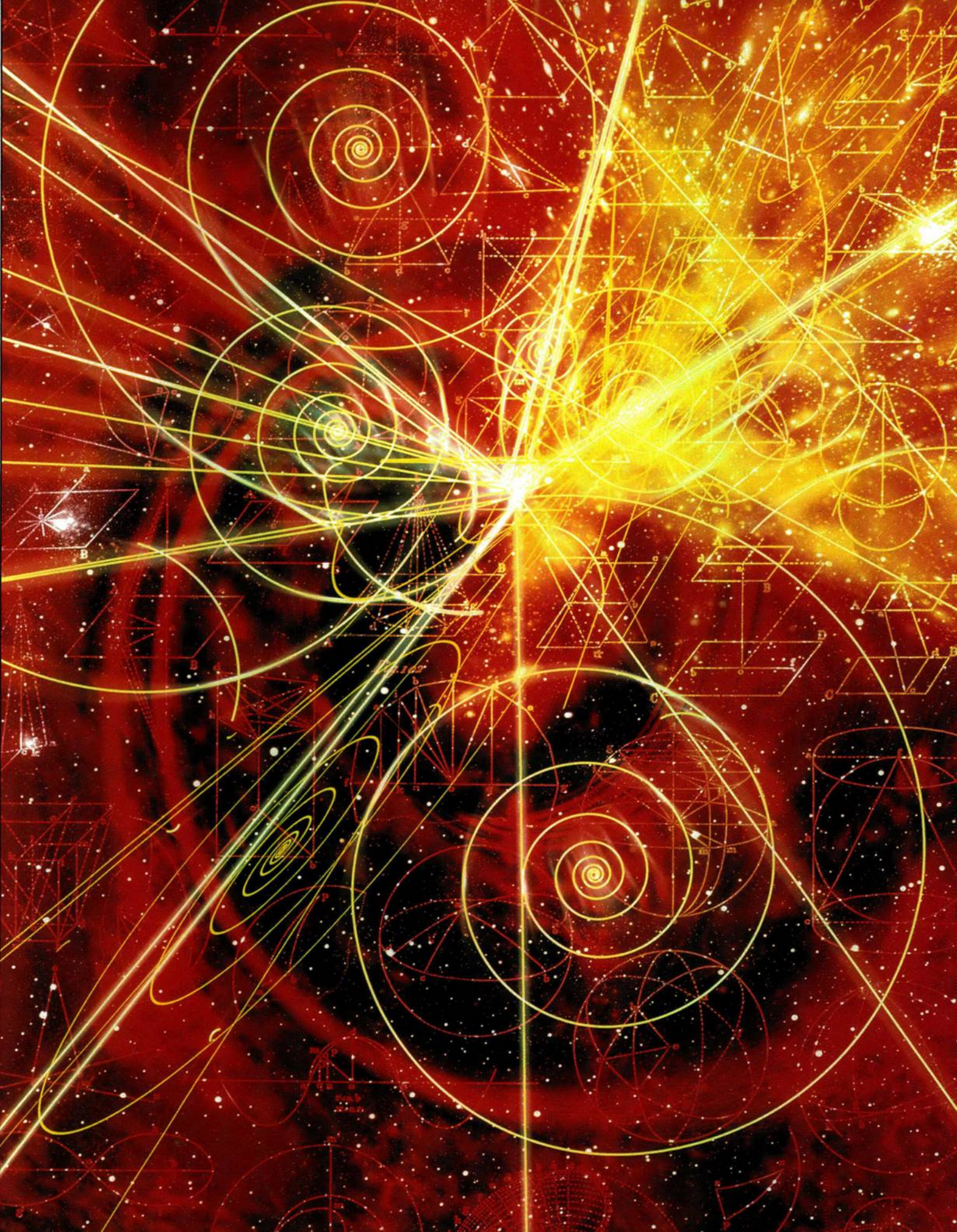
COSMIC INFLATION COMES OF AGE

*More than two decades after cosmic inflation transformed cosmology, one important question remains:
Is the universe a bigger place because of it?*

by Steve Nadis

On December 7, 1979, an unknown young Stanford University physicist named Alan Guth hit upon an idea so powerful, he penned the words SPECTACULAR REALIZATION on a leaf of his equation-strewn notebook. Within a year, the scientific community recognized that Guth's idea was spectacular indeed. After all, Guth's tinkering with the tenets of particle physics had single-handedly cracked nearly every one of cosmology's unsolved riddles.

Guth's grand idea, which he called inflation, seemed to be just what the doctor ordered to mend gaping holes in Big Bang theory at the time. (See "How it all Began," at www.astronomy.com.) In 1979, the standard Big Bang model adequately explained the origin of light elements and the presence of the Cosmic Microwave Background (CMB) left over from the primordial blast. But the standard model fell short on answering a handful of important questions: Why is the universe so uniform on the largest length scales? What caused fluctuations in the matter density of the universe that ultimately led to the formation of stuff like galaxies, planets, and people? And why does the universe contain so much stuff?

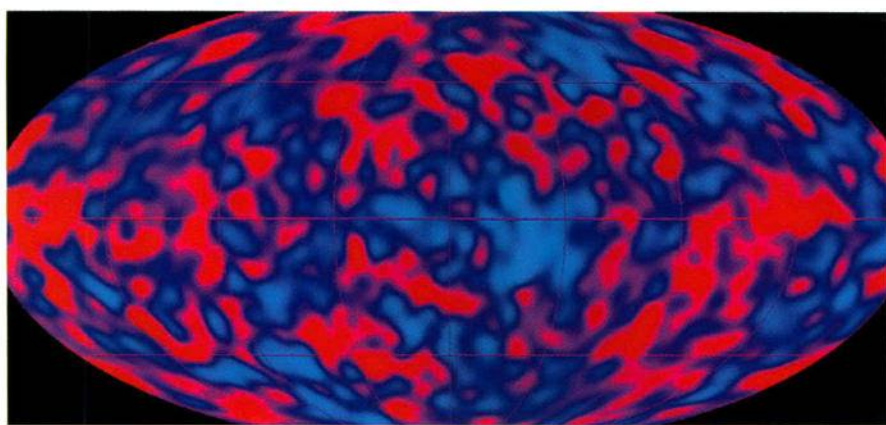


Now more than two decades after Guth's moment of insight, it's worth investigating how well inflation has stood the test of time. On the one hand, inflation is doing well, widely considered an integral component of the new Big Bang cosmology. Yet on the other hand, it still suffers from vagueness. "Although the basic idea still looks very attractive," admits Guth, "we don't know the real details of inflation or the mechanism that drives it." On the leading edge of the twenty-first century, inflation's trial period is quickly coming to a close as astronomers must decide whether inflation will prevail, require modification, or be replaced. The possibilities, as you'll see, are nearly infinite.

FASTER THAN THE SPEED OF LIGHT

As cosmological concepts go, inflation's roots are pretty straightforward. A basic prediction from particle physics states that matter at very high energies (like those expected during the formation of the universe) can assume a variety of unusual forms, including one state that turns gravity upside-down. In this case, massive particles repel rather than attract each other. What's more, matter in such a topsy-turvy state possesses another strange property: Its density remains constant, even as the volume of space it inhabits expands like mad.

In the parlance of particle physics, such a space-filling, antigravity substance can be described by a scalar field. Though they may sound exotic, scalar fields are merely a way of representing an array of numerical values at various points in space. For example, if



you can quantify a particular parameter at multiple locations, such as air pressure at every spot in a room, you've got an air pressure scalar field. Moreover, scalar fields (as far as particle physicists are concerned) are subject to quantum fluctuations. And if the fluctuations in the antigravity scalar field become large enough, a region of space can expand rapidly. If even the tiniest patch of space is filled with an antigravity scalar field, for a brief moment it will swell uniformly and exponentially, like a rising loaf of bread on steroids.

According to Guth's inflationary model, an antigravity scalar field dominated the universe when it was just 10^{-35} seconds old. Fluctuations in this field caused the budding universe, then smaller than the size of a proton, to expand faster than the speed of light. And in the course of roughly a trillionth of a trillionth of a trillionth of a second, the universe doubled in size 100 times over. But almost as quickly as it began, inflation ground to a halt as the antigravity material became unsta-

Without inflation, astronomers would be hard-pressed to explain the CMB's startling uniformity, which deviates from perfection by less than one part in 100,000. NASA/COBE

ble, eventually releasing energy transformed during the inflation-induced expansion into radiation and matter. Finally, the universe continued to expand at the much more moderate, yet apparently accelerating, pace we observe today.

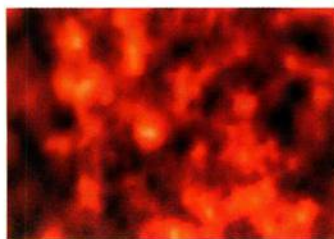
JELL-O AND CHAOS

Despite its initial success, inflation has never been immune from criticism. Guth's original formulation, for example, had a crippling weakness, which he acknowledged in his 1981 paper and explained at greater length in a subsequent paper written with Erick Weinberg of Columbia University. Guth mistakenly pictured the phase transition between the antigravity era and the radiation-dominated era that followed as something akin to water boiling. In this scenario, the post-inflation universe was filled with "bubbles"

INFLATION FLATTENS THE UNIVERSE

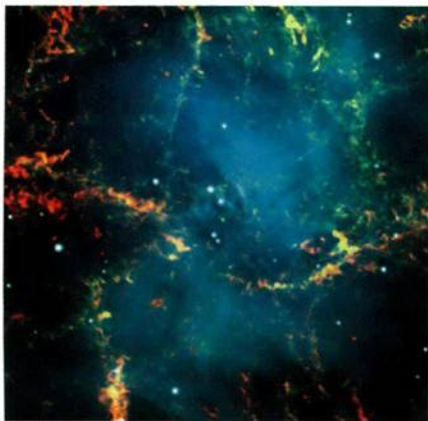
In the last few years, inflation has received a welcome boost from several research collaborations observing the ubiquitous Cosmic Microwave Background (CMB), remnant radiation from the creation of the universe. As it turns out, small temperature variations in the CMB speak volumes about the geometry of the universe and its origin, just like inflation. What's more, inflation would suffer a fatal blow if the theory didn't mesh with CMB observations.

The geometry of the universe can take on one of three states, depending on the overall density of matter. If the density is equal to a benchmark called the critical density, the geometry is flat, like a sheet of paper. If the density is



above or below critical, the geometry is positively curved (like the surface of a sphere) or negatively curved (like the surface of a saddle), respectively. Multi-wavelength observations indicate that the universe is very likely flat.

Because inflation takes a small, homogenous region of the universe and expands the region exponentially until it becomes flat, it too predicts that the geometry of the universe should be flat. Recently, the high-altitude balloon experiments BOOMERanG and MAXIMA have shown that the fluctuations that give the CMB its characteristic mottled uniformity cluster around one degree in angular size, another trait that strongly suggests a flat universe.



that never had a chance to collide and merge owing to the rapid expansion. “The formation of these bubbles would have made things so inhomogeneous, it would look nothing like the universe we see,” says Guth.

The first successful way around that problem, called “new inflation,” was devised in late-1981 by Andrei Linde, a physicist now at Stanford, and independently by Paul Steinhardt and Andreas Albrecht, who are now at Princeton and the University of California, Davis, respectively. “The boiling of water was replaced by a milder, slower transition, which was more like the congealing of Jell-O,” Guth says. That slowed down the pace of inflation, giving each bubble the chance to expand to fantastic dimensions, far bigger than the observable universe. If this view is right, says Guth, “we’re living inside a bubble so large, we couldn’t possibly see the edge.”

Steinhardt and his colleagues developed another prescription for stalling inflation by adjusting the behavior of the antigravity scalar field, which physicists also describe in terms of its potential energy. When the field is at its maximum potential energy, it’s like a ball on top of a hill. As the system naturally moves toward equilibrium, in the same way that a ball will naturally roll downhill, its potential energy becomes kinetic energy. The kinetic energy, in turn, is converted to radiation, which ultimately halts inflation. As a bonus, some of that radiation later gets converted into matter that fills the universe.

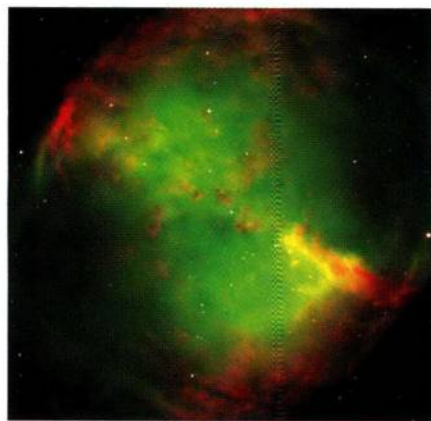
Nevertheless, Linde later rejected new inflation after realizing that the universe need not have been spawned from a hot, dense phase as the Big Bang model predicts. In 1983, he proposed a modification called “chaotic inflation.” (Incidentally, Steinhardt and Guth,



Inflation models easily account for the vast number of particles (about 10^{90}) in the visible universe because of the exponential nature of the expansion. By contrast, standard Big-Bang models don’t yield enough material to form celestial beauties like the Crab Nebula (M1), RCW 108, and the Dumbbell Nebula (M27). ESO

among others, think new inflation may still be viable.) The basic premise of chaotic inflation is that, out of sheer randomness, the scalar field can have a variety of energy values. In some places the scalar field is sitting at its “ground state,” near the potential energy minimum, while at other places it happens to possess more potential energy. The region of space near the minimum stays small and doesn’t inflate, whereas the region with excess potential energy will inflate and become exponentially large. Despite its name, the concept has nothing to do with “chaos theory,” which describes unpredictable systems that grow increasingly disordered over time. “This is really the opposite,” Linde says. “Here you start with chaos and end with perfection.”

In 1989, Steinhardt and his graduate student, Daile La, introduced the notion of “extended inflation,” which



offered a new way to end inflation by proposing changes in the behavior of gravity at high energies to slow the universe’s expansion. A host of other inflationary models have since been proposed, including “hyper-extended inflation,” “open inflation,” and “two-round inflation.” All of these models attempt to explain three things: How does inflation start, what drives it, and how do you end it? “It’s like a Chinese menu,” Steinhardt says. “You have a couple of choices for parts A, B, and C. Although the number of concepts isn’t that great, you can put them together in many different ways.”



The secrets of how galaxy clusters, like Abell 98, come together from quantum fluctuations can be found with inflation. WIYN/NOAO/NSF/M. Pierce

It might seem surprising that models missing key details — such as the energy scale at which inflation proceeds — can perform so well (see “Flattening the Universe,” page 30). “Oddly enough, we can make accurate predictions even though we don’t fully understand the mechanism behind inflation,” says Guth.

SURFING THE CMB

But how do we go about separating the most plausible models from the more dubious ones? “We can rule out most inflationary theories simply by studying the microwave background in greater detail,” says Linde. Those tests can help narrow down the field, Guth agrees, “but we will not find a unique solution from any experiments that are currently planned.”

Meanwhile, astronomers are pinning their hopes on gravity waves produced in the universe’s first moment as our best chance for studying the conditions that triggered inflation. There’s no prospect of seeing the most energetic gravity waves directly, because they would span the entire universe and it would take an instrument at least that big to detect

them. The strategy, instead, is to look for the subtle impressions these waves would make on the CMB. The recently launched Microwave Anisotropy Probe (MAP) might have a prayer of seeing that faint imprint, and the higher-resolution Planck spacecraft (scheduled for launch in March 2007) will have an even better shot. “Ultimately, this job will get done, even if Planck can’t do it, because there’s so much riding on this measurement,” says University of Pennsylvania physicist Max Tegmark.

Any future detection of the imprint left by primordial gravity waves could reveal the energy scale of inflation, which is equivalent to showing when — and at what temperature — the expansion began. The shape of the gravity curve relates directly to the energy of the antigravity scalar field, which will tell researchers about the physics governing inflation. “These gravity waves are the only pieces of evidence remaining from the early, early universe,” says Tegmark. “Until somebody comes up with another idea, they’re our only hope of measuring anything that tells us about this epoch.”

But we won’t have to wait a decade to learn anything new, he adds. “MAP

should tell us exactly how flat space is. The error bars will shrink a lot in the next two years. And it’s not a foregone conclusion that inflation will still agree.”

WHAT’S THE ALTERNATIVE?

If not inflation, what else can explain the riddles the theory was designed to address? Earlier this year, Steinhardt and three collaborators offered a new “ekpyrotic” scenario (see “The Universe Goes Pyrotechnic,” page 37), which he says can resolve the same problems in a “conceptually different and observationally distinguishable way.” This model, inspired by string theory, postulates that our expanding universe “was created from the collision of two, three-dimensional worlds moving along a hidden extra dimension,” explains Steinhardt. Although the idea sounds wacky, its predictions are straightforward: The gravity wave signature in the microwave background should drop off sharply at long wavelengths. Inflation, by contrast, predicts a “scale-invariant” signature with roughly equal amplitude waves on all scales.

“I still like inflation,” Steinhardt adds. “It’s a wonderful theory that may prove to be right. But as a scientist, I have to ask: ‘Is there another way to do it?’” A successful theory can lead to complacency, he points out, whereas competing theories that make very different predictions can push science forward.

Although Guth agrees that alternative models, like the ekpyrotic scenario, are good, so long as they’re reasonable, he admits that he would be disappointed if this alternative view proves correct. “But science has to go on and new ideas have to be tested,” he says.

“If inflation is eventually replaced by something completely different, it will have served a valuable purpose nevertheless,” continues Guth. “By providing a framework for discussing properties of the early universe and by highlighting what needs to be explained, it has set the stage for what must follow.” **A**

Steve Nadis is a freelance writer based in Cambridge, Massachusetts. His last article for Astronomy, “Size Matters,” appeared in the March 2002 issue.

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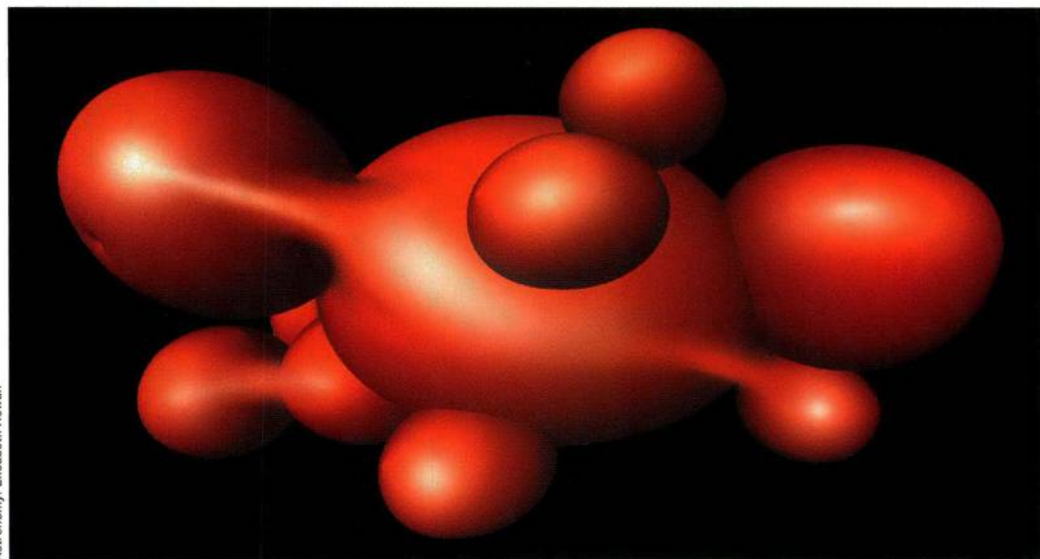


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Universes Spring Eternal?



Astronomy: Elisabeth Rowan

In 1983, Alexander Vilenkin of Tufts University made the astonishing suggestion that almost all inflation models are “eternal” — once the process starts, it never ends.

Inflation is like a chain reaction, stopping in one region of space only to start in another, ultimately spawning an infinite number of “pocket universes.”

Vilenkin has continued to explore the implications of this idea, as have Andrei Linde of Stanford and Alan Guth of MIT. Linde, for example, views the universe as a “self-reproducing fractal.” He says, “We live in just one of the bubbles that has properties conducive to life, while other bubbles may be entirely different from ours.” He adds, “They used to throw eggs at people who discussed the anthropic principle (the notion that the possible initial conditions of the universe are limited to only those that give rise to the evolution of life) at conferences. With inflation, it is no longer metaphysics, but physics.”

The idea of a process that spins off universes faster than dot.com companies in the

late-1990s may seem farfetched. But to Guth, “it seems far more plausible that our universe was the result of mass reproduction rather than one created from a unique cosmic event.”

Even if we accept the notion that, once started, inflation continues without end, then it still leaves open the nagging question of what spawned the material that triggered inflation in the first place.

“Inflation does not explain how the universe began, nor does it set out to do so,” says Guth. “But it does provide a physical mechanism for taking a subatomic speck and producing a vast region of space-time filled with matter. So, in essence, inflation reduces the question of the universe’s origin to the question of how we get that subatomic speck.” Although this seemingly lesser question will also not be easy to answer, at least it’s less daunting to contemplate. — STEVE NADIS

The Universe Goes Pyrotechnic



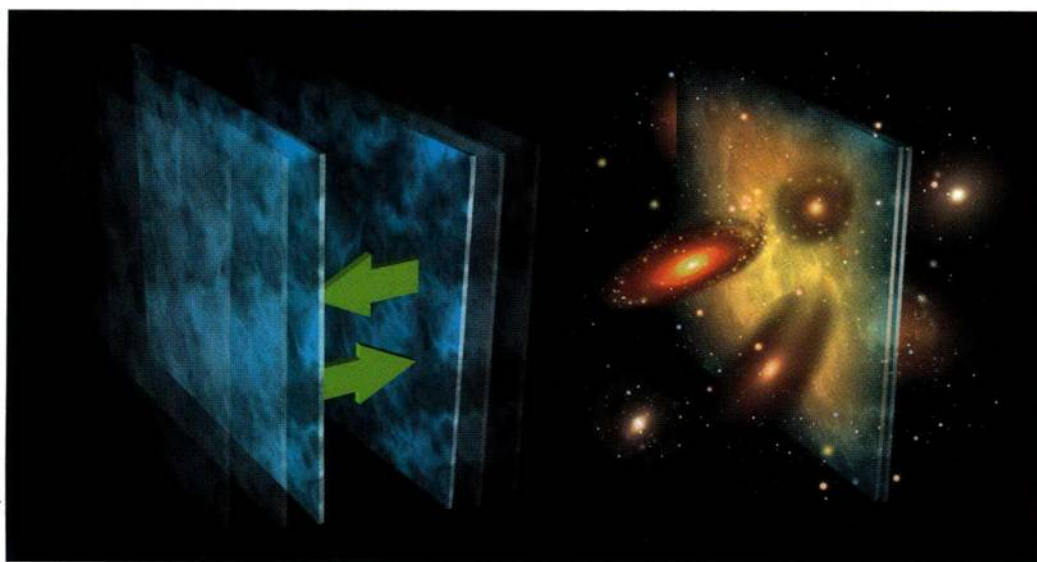
In March 2001, Justin Khoury and Paul Steinhardt of Princeton University, along with Neil Turok of Cambridge University and Burt Ovrut of the University of Pennsylvania, unveiled a potentially serious alternative to inflation. Their so-called “ekpyrotic model,” derived from the Greek term ekpyrosis, meaning “conflagration,” is based on so-called M-theory — the latest, most fundamental version of superstring theory. According to M-theorists, our universe might lie on a three-dimensional sheet-like membrane, or “brane,” which floats in a hidden fifth dimension (the fourth dimension being time). The theory also posits the existence of six higher spatial dimensions, all tied up in extremely tiny circles, smaller than the radius of a single proton.

In the ekpyrotic scheme, the driving force behind the universe’s expansion comes not from inflation but from a collision between our universe and another parallel “brane” universe from an imperceptible dimension. This scenario does not contradict the idea of a universe that has expanded and cooled since

the Big Bang. “What our model does is amend the earliest moments of the story,” says Steinhardt, offering a different explanation for what put the “bang” in the Big Bang.

This model was challenged about a week later in a 21-page paper written by Andrei Linde and his wife, Renata Kallosh, both of Stanford, along with Lev Kofman of the University of Toronto. The model works better, they say, by simply changing the sign of one parameter. They call their “improved scenario” the “pyrotechnic universe,” while acknowledging it still suffers from problems that beset the original version.

Steinhardt is unconvinced by Linde and company’s critique. “This is a whole different approach, rather than a specific model,” he says. It’s worthwhile, in any case, to try to devise alternative approaches, he adds. “Either we’ll learn that this is a viable alternative or that it’s hard to come up with an alternative to inflation.” — S. N.



Astronomy: Elisabeth Rowan



Quintessential Inflation



Astronomy: Elisabeth Rowan

Cosmologists now believe that roughly two-thirds of the stuff that makes up the universe consists of mysterious “dark energy” — not to be confused with the equally puzzling, though less abundant, dark matter. A prime candidate for this dark energy, which pushes the universe apart ever faster, is a hypothetical form of matter that permeates all space called “quintessence.”

Like inflation, quintessence is thought to have somehow originated when the universe was just 10^{-35} seconds old. And it is also driven by a scalar field whose energy varies gradually (See “Is Inflation Supernatural?”, page 39). The resemblance is not coincidental, according to Princeton’s Paul Steinhardt, because the idea was modeled after inflation. The big difference is the energy and time scale: Inflation occurred quickly at very high energies, whereas the scalar field responsible for quintessence operates at much lower energies over a much longer time frame. “It looks like the universe is sandwiched between two periods

of cosmic acceleration,” says Steinhardt.

“The currently observed acceleration of the universe — if it’s real, and it certainly appears so — provides direct evidence that gravity can act repulsively,” says MIT’s Alan Guth. “That gives us more confidence right now that inflation is correct.”

But some believe there may be an even stronger link between inflation and quintessence. In 1999 Alexander Vilenkin of Tufts University and James Peebles of Princeton proposed that the same scalar field could drive both inflation and quintessence. The premise of this model is that the field responsible for inflation operates in a high-energy regime, but its intensity drops off quickly, and its effects — masked by other more energetic phenomena — do not become apparent until much later in the universe’s history.

“I’m not ready to say that this is better than other models, but at least it’s a testable scenario,” Vilenkin notes. — S. N.

Is Inflation Supernatural?

What if inflation is driven by two scalar fields instead of just one, as is typical in most cosmological models? The idea makes sense to MIT physicist Lisa Randall, who says scalar fields often operate in concert.

“Previous inflationary models don’t do a good job of ending inflation,” Randall says. “The main thing lacking was a switching mechanism. The idea of having a separate field to turn off inflation seems to me like a dramatic improvement.”

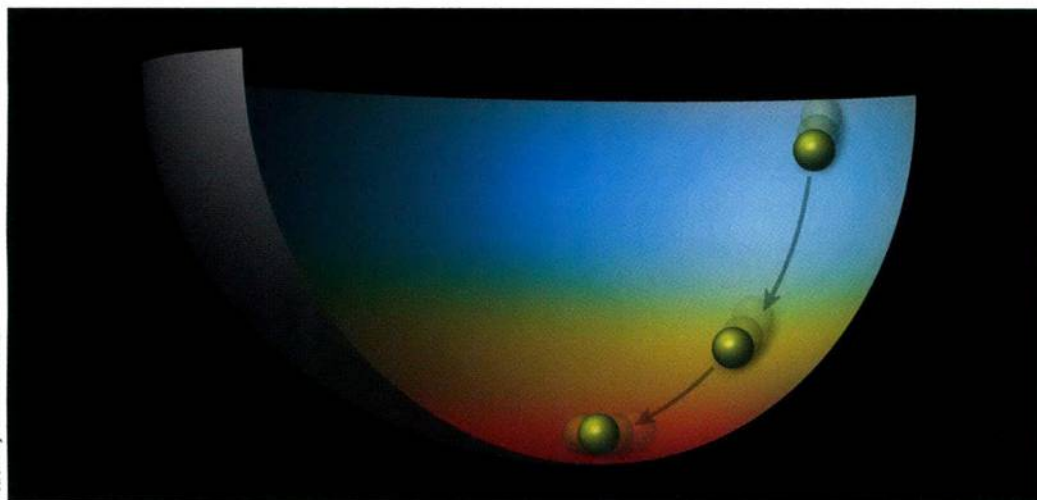
Randall and Marin Soljagic, her graduate student at the time, teamed up with Alan Guth, MIT’s resident inflation expert, to devise their so-called “supernatural model.” One field in this model provides the bulk of the energy density needed to drive inflation, while the second field acts as a trigger to turn it off. “We think it works like a seesaw,” Guth explains. “The energy field holds down one end, while the second field presses on the other end with increasing force, as if sand

were being dropped on it. Eventually the whole thing tips over and inflation ends.”

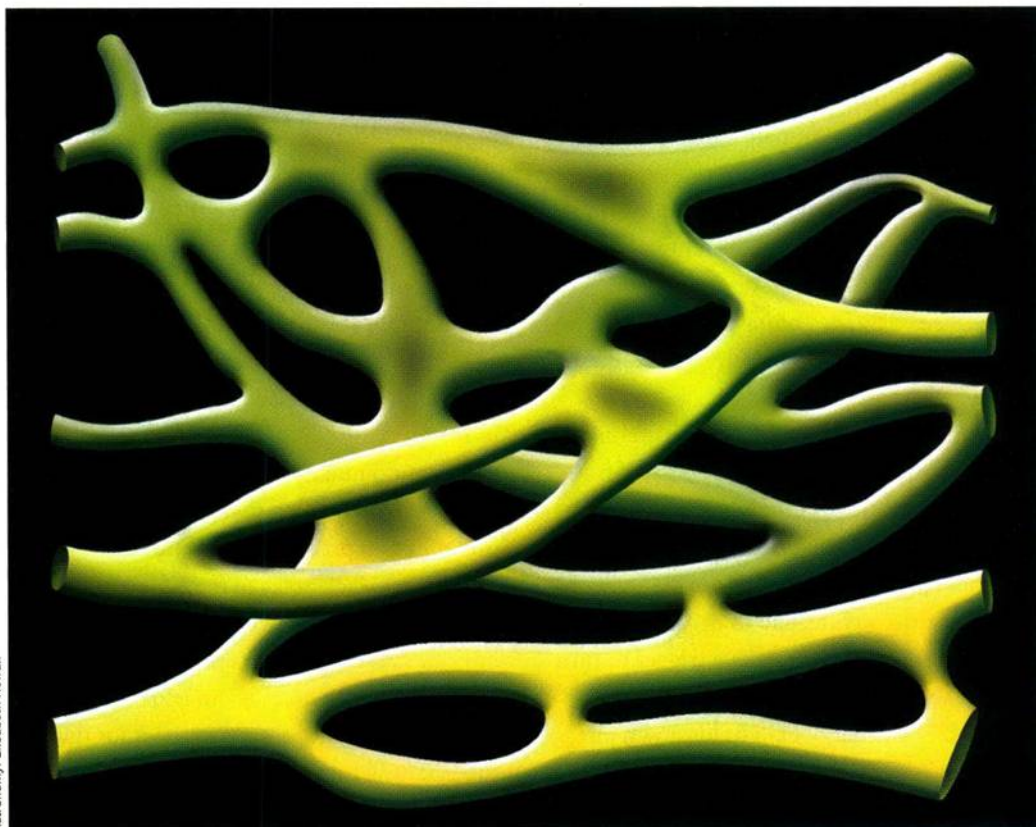
He acknowledges that in reality there may be even more than two scalar fields at play. “Supersymmetry models usually have a large number of scalar fields,” Guth says. “In that case, supernatural inflation might be an improvement over the status quo, but still an oversimplification.”

One way to find out if the model is right is to look for a sharp peak at short wavelengths in the spectrum of the universe’s microwave background radiation. For technical reasons, that peak will be hard to detect. But supernatural inflation predicts the creation of primordial black holes in the early universe, long before other structures form. Studies that indicate galaxy formation is “seeded” by primordial black holes — an issue yet to be resolved — might provide support for the supernatural model before the completion of painstaking microwave measurements. — S. N.

The antigravity scalar field is analogous to a marble rolling inside a bowl. When the field's potential energy is maximized, corresponding to the marble near the rim of the bowl, inflation occurs, causing a space-time region to grow exponentially large. As kinetic energy of the field converts to radiation, in the same way that the marble's potential energy becomes kinetic energy and heat as it falls, inflation halts and the system soon comes to rest.



The Search for a Final Theory



Astronomy: Elisabeth Rowan

Quantum Field Theory, upon which inflation now rests, may not be adequate to explain the universe's sudden expansion, says MIT's Alan Guth. Instead, we may need a theory of so-called "quantum gravity" to really understand the mechanism driving inflation. Quantum gravity, which is still in its formative stages, is an attempt to develop a "theory of everything" (T.O.E.) — one that unites the intricacies of quantum mechanics with the force of gravity as described by Einstein's general relativity. The underlying hope is to combine the strengths of both particle physics and cosmology into a single, powerful tool.

String theory, which describes a universe with more dimensions than we can readily perceive, represents one approach to establish-

ing a quantum gravity theory. Ultimately, we may have to describe inflation in terms of strings, says Guth.

"At the moment, there's a large variety of string theory models, which is a sign we don't know enough to converge on any one soon," says Alexander Vilenkin of Tufts University. "The same holds for inflationary models, and I think the two things are connected. If we're lucky, one day we'll converge on a unique theory, but I don't see that happening anytime soon." — S. N.

A

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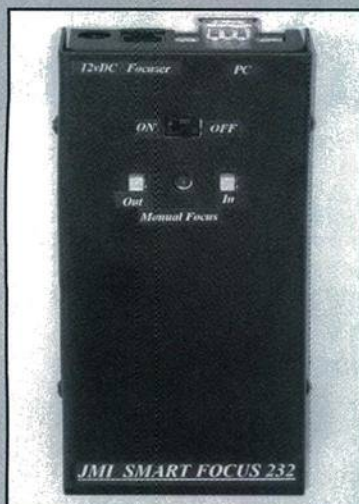


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Comet Borrelly's Dark Nature

by Richard Talcott

*Long after its mission
was supposed to end,
Deep Space 1 sent back
the most detailed images
ever of a comet's nucleus.*

As the sun beat down on its surface, a patch of Comet Borrelly exploded into action. Jets of gas and dust blasted into space, barely slowed by the weak gravitational pull of the comet's nucleus. Meanwhile, eager astronomers pointed the instruments onboard Deep Space 1 toward the comet, hoping the spacecraft could help them understand this visitor to the inner solar system.

And help it did. "Deep Space 1 plunged into the heart of Comet Borrelly and lived to tell every detail of its spine-tingling adventure," acclaims Marc Rayman, the mission's project manager at NASA's Jet Propulsion Laboratory. The black-and-white images snapped by the spacecraft's camera proved to be the sharpest ever taken of a comet's nucleus. They showed a remarkably dark surface with varied terrain punctuated by active jets expelling dust and gas. Other measurements revealed that the nucleus does not lie at the center of the giant cloud of gas and dust known as the coma.

The risky encounter between Deep Space 1 — originally designed for an 11-month mission but extended for two additional years — and Comet Borrelly went off with few problems. For several hours on September 22, 2001, mission operators commanded a suite of four instruments to observe Borrelly and its environment. In addition to the black-and-white images, the spacecraft returned infrared spectra, data on ions and electrons in the comet's vicinity, and measurements of the magnetic field and plasma waves around Borrelly. Not bad for a spacecraft designed to test cutting-edge technologies, not to study comets (see "A Technology Tale").

One of the few glitches occurred well before Deep Space 1 even arrived at Comet Borrelly. Nearly a month prior to the encounter, mission planners had the spacecraft try to locate the comet — with no success. It took four days before optical navigation images found the comet, and it was more than a thousand miles from where it was supposed to be. Astronomers had used ground-based observations to predict the comet's position, but the measurements proved surprisingly inaccurate. The optical navigation images helped target Deep Space 1 and put the space-

craft on a course that carried it within just 1,349 miles (2,171 km) of the comet's nucleus.

The flyby didn't last very long, with the spacecraft whizzing by the comet at a relative speed of 10.3 miles per second (16.6 km per second). Deep Space 1 started taking images with its Miniature Integrated Camera and Spectrometer 32 minutes before it passed closest to the nucleus and continued until 160 seconds before closest approach, as planned.

The best image came from a distance of 2,123 miles (3,417 km) and shows the 5-mile-long nucleus at a resolution of about 150 feet per pixel. That compares with a peak resolution of 200 feet per pixel for the best previous images, taken by Europe's Giotto

spacecraft when it flew past Comet Halley in March 1986. Although the Giotto camera performed roughly ten times better than Deep Space 1's, it had to look through a much dustier environment — Halley's nucleus spews about 30 times as much dust and gas as Borrelly. "At Halley we were looking through a blizzard," says Laurence Soderblom, leader of Deep Space 1's imaging team and a geologist at the U.S. Geological Survey in Flagstaff, Arizona. "At Borrelly, we had a clear day."

The images reveal a surface darker than any other in the inner solar system. Contrary to popular opinion, comets are not dazzling snowballs flying through space. Yet Borrelly sets a new standard for such objects: The comet's albedo — the fraction of

A Technology Tale

On October 24, 1998, NASA's New Millennium Program got off to a rousing start with the launch of Deep Space 1. NASA designed this program to test cutting-edge technology in space with the hope that future missions would incorporate successful aspects to probe Earth, the solar system, and the universe at large. Deep Space 1 proved that the concept can work gloriously well. (Unfortunately, its successor, Deep Space 2 — twin probes designed to penetrate Mars's surface — failed along with Mars Polar Lander in December 1999.)

Designed and built in just three years at a cost of approximately \$150 million, the refrigerator-sized spacecraft flight-tested a dozen new technologies. Perhaps the most intriguing was an ion engine, a futuristic system that used ionized xenon atoms instead of standard chemical propellants. The engine created the ions by bombarding xenon atoms with a beam of electrons. It then generated thrust by passing the ions through an electric field, accelerating them to 60,000 miles per hour and shooting them out the back of the spacecraft. Although each atom provided a minuscule push, the combined kick from 180 pounds of xenon did the trick. The ion engine operated for 677 days and used more than 90 percent of the available fuel.

Deep Space 1 also tested autonomous navigation software — a key step on the path to artificial intelligence for spacecraft. NASA's Deep Impact mission (see "Probing a Comet's Character" on page 45) will use such a system to reach the nucleus of Comet Tempel 1. Among the other technologies used were a solar-power system that used cylindrical lenses to concentrate sunlight onto an array of solar cells, a low-power electronics package, and a communications system that reduced reliance on the Deep Space Network.

Near the end of its primary mission, Deep Space 1 flew past the asteroid Braille. It then embarked on an extended mission that culminated with the Comet Borrelly flyby and a hyperextended mission to test the technologies one final time. Engineers turned off the ion engine on December 18, 2001, though the radio receiver will be left on in case future generations want to contact the spacecraft. — R. T.



incident sunlight it reflects — averages just 3 percent, darker than a charcoal briquette and about the same as photocopier toner.

And the albedo of some regions dips below 1 percent. Only the rings of Uranus, the mysterious dark side of Saturn's moon Iapetus, and perhaps a few of the darkest asteroids can compare, and all those objects seem to be made of the primitive material common in the outer solar system. Borrelly appears to be unique in the inner solar system.

The images show enough detail for planetary scientists to study the geology of a comet's nucleus for the first time. "These pictures have told us that comet nuclei are far more complex than we ever imagined," says Soderblom. "They have rugged terrain, smooth rolling plains, deep fractures, and very dark material." Two types of terrain dominate Borrelly's surface. One appears brighter and smoother than average and lies near where the jets appear to be active. Some planetary scientists think the jets may help resurface these areas. The second type appears darker and rougher and likely represents older material. Still, craters do not seem to be ubiquitous, implying a geologically young surface.

The jets appear to emanate from the smoothly rolling plains, and long-exposure images show the strongest one to have three distinct components. It appears that this jet lies near the rotation axis of the nucleus and was experiencing constant sunlight at the time of the flyby.

The Plasma Experiment for Planetary Exploration (PEPE) measured the electrons and ions in Borrelly's coma throughout the flyby. The instrument found that as the charged particles that compose the solar wind ram into ions in the comet's coma, the wind's speed drops from about 200 miles per second to less than 10 miles per second. Surprisingly, the team found that the solar wind flowed symmetrically around the coma, but that the nucleus was a couple of thousand miles off center.

The closest view of Comet Borrelly's dark nucleus (top) shows a variety of terrains with mesas, dark spots, fractures, ridges, and craters. Rugged dark terrain and smooth, brighter terrain typify the comet's surface from in close (above left). The final three long-exposure images have been enhanced to bring out details in the comet's jets. NASA/JPL

“The formation of the coma is not the simple process we once thought it was,” says PEPE team leader David Young of the University of Michigan. “Most of the charged particles are formed to one side,” presumably the side with the strong jets.

After Deep Space 1 returned all its comet data, much of it still being analyzed, the extended mission officially came to an end. But Deep Space 1 then entered a brief hyperextended mission in which all the hardware technologies tested during the primary mission were exercised again. Then, on December 18, the plug was pulled — the objectives more than fulfilled. “I’m not sad it’s ending,” says Rayman, “I’m happy it accomplished so much.” **A**

On September 22, ground-based astronomers captured this view of Comet Borrelly from Kitt Peak National Observatory in Arizona. NOAO/JA



Probing a Comet's Character

Deep Space 1 is just one in a long line of spacecraft that have changed the way we look at comets. From the International Cometary Explorer (ICE) that flew past Comet Giacobini-Zinner in 1985, through the flotilla of spacecraft that examined Comet Halley, and on to the ambitious missions of the future, scientists are learning plenty about these enigmatic survivors from the earliest stages of the solar system.

Spacecraft	Comet	Year	Major Accomplishments or Objectives
ICE	Giacobini-Zinner	1985	Flew through comet's tail; studied interaction with solar wind
Vega	Halley	1986	Imaged nucleus; measured surprisingly warm temperature of nucleus
Sakigake	Halley	1986	Studied interaction between solar wind and cometary atmosphere
Suisei	Halley	1986	Took ultraviolet images; studied solar wind
Giotto	Halley	1986	First closeup images of a comet's nucleus, showing black crust and bright jets; measured size, composition, and velocity of dust particles; measured composition of gas
Giotto	Grigg-Skjellerup	1992	Closest comet flyby to date; detected two brightness peaks and unusual magnetic waves near comet
Deep Space 1	Borrelly	2001	Highest-resolution images to date
Contour	Encke S-W 3	2003 2006	Multiple flybys (Encke in 2003, Schwassmann-Wachmann 3 in 2006); high-resolution imaging; detailed analysis of dust and gas composition
Stardust	Wild 2	2004	Return comet samples to Earth
Deep Impact	Tempel 1	2005	Impact comet and observe resulting crater
Rosetta	Wirtanen	2011	Enter orbit around comet and study in detail for two years

Protecting the Past

by Stephen Hawking



Is Time Travel Possible?

MY FRIEND and colleague Kip Thorne, with whom I have had a number of bets, is not one to follow the accepted line in physics just because everyone else does. This led him to have the courage to be the first serious scientist to discuss time travel as a practical possibility.

It is tricky to speculate openly about time travel. One risks either an outcry at the waste of public money being spent on something so ridiculous or a demand that the research be classified for military purposes. After all, how could we protect ourselves against someone with a time machine? They might change history and rule the world. There are only a few of us foolhardy enough to work on a subject that is so politically incorrect in physics circles. We disguise the fact by using technical terms that are code for time travel.

The basis of all modern discussions of time travel is Einstein's general theory of relativity. The Einstein equations made space and time dynamic by describing how they were curved and distorted by the matter and energy in the universe. In general relativity someone's personal time as measured by their wristwatch would always increase, just as it did in Newtonian theory or the flat spacetime of special relativity. But there was now the possibility that spacetime could be warped so much that you could go off in a spaceship and come back before you set out.

One way this could happen is if there were wormholes — tubes of spacetime that connect different regions of space and time. The idea is that you steer your spaceship into one mouth of the wormhole and come out of the other mouth in a different place and at a different time.

Wormholes, if they exist, would be the solution to the speed limit problem in space: it would take tens of thousands of years to cross the galaxy in a spaceship that traveled at less than the speed of light, as relativity demands. But you might go through a wormhole to the other side of the galaxy and be back in time for dinner. However, one can show that if wormholes exist, you could also use them to get back before you set out. So you might think that you could do something like blowing up the rocket on its launch pad to prevent your setting out in the first place. This is a variation of the grandfather paradox: what happens if you go back and kill your grandfather before your father was conceived?

Of course, this is a paradox only if you believe you have free will to do what you like when you go back in time. This book concentrates on whether the laws of physics allow spacetime to be so warped that a macroscopic body such as a spaceship can return to its own past. According to Einstein's theory, a spaceship necessarily travels at less than the local speed of light and follows what is called a timelike path through spacetime. Thus one can formulate the question in technical terms: does spacetime admit timelike curves that are closed — that is, that return to their starting point again and again? I shall refer to such paths as "time loops."



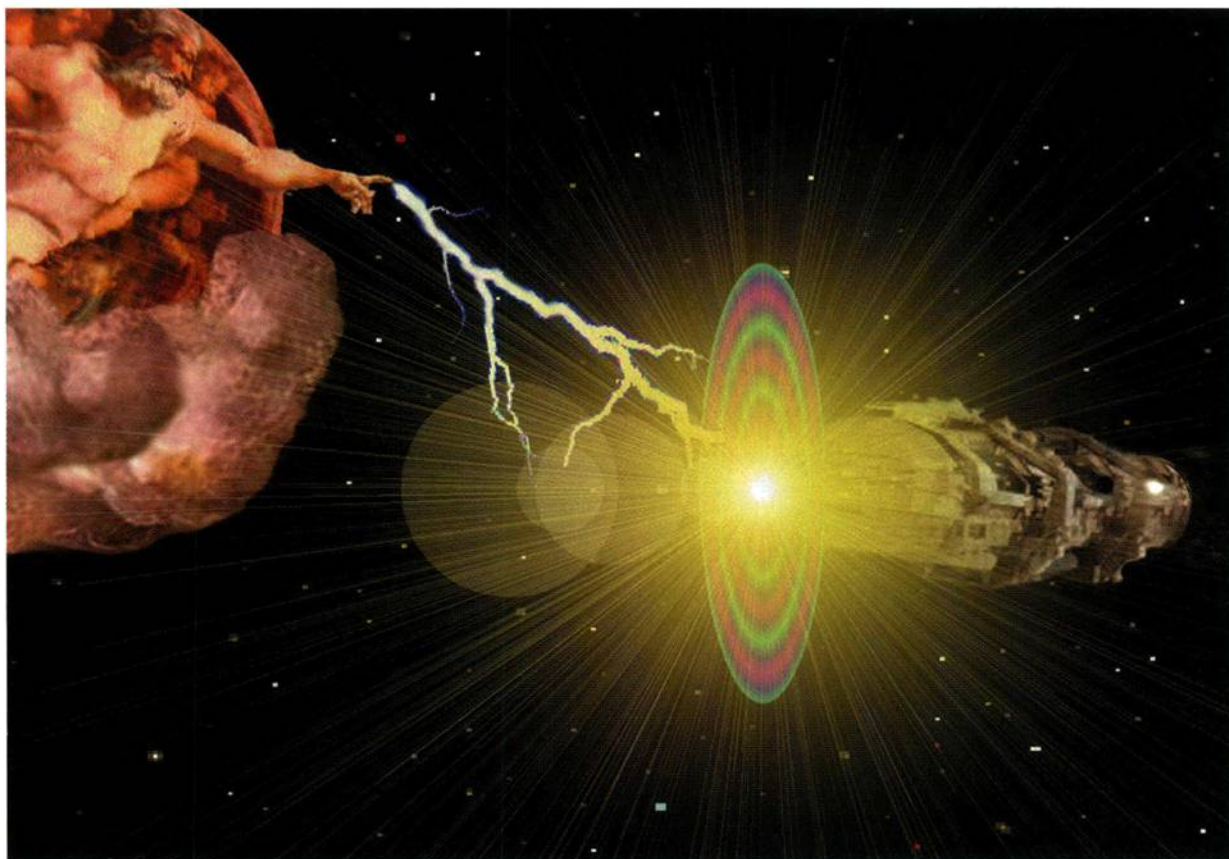
Could an advanced civilization go back and change the past?

TIME TRAVEL is possible in a region of spacetime in which there are time loops, paths that move at less than the speed of light but which nevertheless manage to come back to the place and time they started because of the warping of spacetime. Since I have assumed there were no time loops in the distant past, there must be what I call a time travel "horizon," the boundary separating the region of time loops from the region without them.

Time travel horizons are rather like black hole horizons. While a black hole horizon is formed by light rays that just miss falling into the black hole, a time travel horizon is formed by light rays on the verge of meeting up with themselves. I then take as my criterion for a time machine what I call a finitely generated horizon — that is, a horizon

that is formed by light rays that all emerge from a bounded region. In other words, they don't come in from infinity or from a singularity, but originate from a finite region containing time loops — the sort of region our advanced civilization is supposed to create.

In adopting this definition as the footprint of a time machine, we have the advantage of being able to use the machinery that Roger Penrose and I developed to study singularities and black holes. Even without using the Einstein equations, I can show that, in general, a finitely generated horizon will contain a light ray that actually meets up with itself — that is, a light ray that keeps coming back to the same point over and over again. Each time the light came around it would be more and more blue-shifted, so the images would get bluer and bluer. The wave crests of a pulse of light will get closer and closer together and the light will get around in shorter and shorter intervals of its time. In fact, a particle of light would have only a finite history, as defined



by its own measure of time, even though it went around and around in a finite region and did not hit a curvature singularity.

THE EVAPORATION OF BLACK HOLES shows that on the quantum level the energy density can sometimes be negative and warp spacetime in the direction that would be needed to build a time machine. Thus we might imagine that some very advanced civilization could arrange things so that the energy density is sufficiently negative to form a time machine that could be used by macroscopic objects such as spaceships. However, there's an important difference between a black hole horizon, which is formed by light rays that just keep going, and the horizon in a time machine, which contains closed light rays that keep going around and around. A virtual particle moving on such a closed path would bring its ground state energy back to the same point again and again. One would therefore expect the energy density to be infinite on the horizon — the boundary of the time machine, the region in which one can travel into the past. This is borne out by explicit calculations in a few backgrounds that are simple enough for exact calculations. It would mean that a person or a space probe that tried to cross the horizon to get into the time machine would get wiped out by a bolt of radiation. So the future looks black for time travel — or should one say blindingly white?

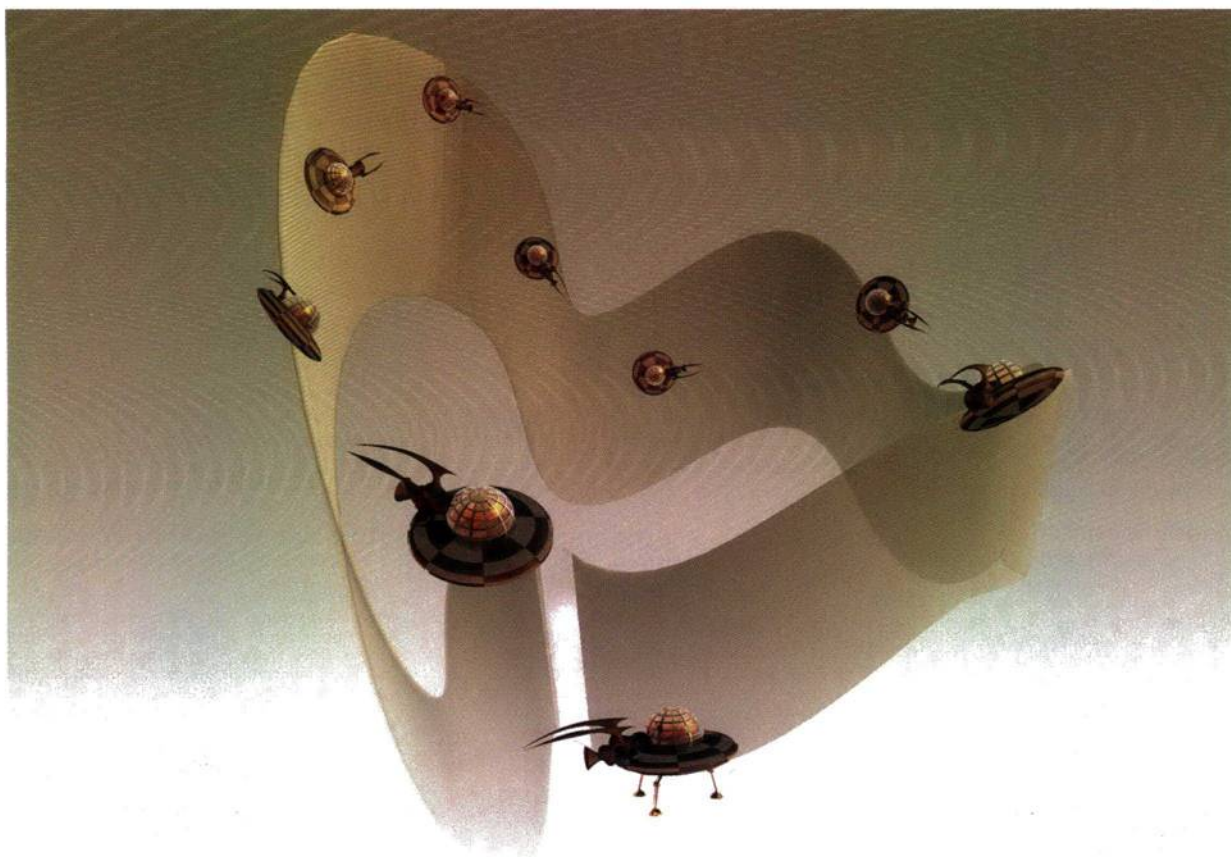
The energy density of matter depends on the state it is in, so it is possible that an advanced civilization might be able to make the energy density finite on the boundary of the time machine by “freezing out” or removing the virtual particles that go around and around in a

Without knowing for certain if time travel is indeed possible, physicists must consider whether simply entering a time machine could trigger a discharge of radiation.

closed loop. It is not clear, however, that such a time machine would be stable: the least disturbance, such as someone crossing the horizon to enter the time machine, might set off circulating virtual particles and trigger a bolt of lightning. This is a question that physicists should be free to discuss without being laughed to scorn. Even if it turns out that time travel is impossible, it is important that we understand why it is impossible.

THE EINSTEIN UNIVERSE does not represent the universe we live in because it is not expanding. Nevertheless, it is a convenient background to use when discussing time travel, because it is simple enough that one can do the sum over histories. Forgetting about time travel for the moment, consider matter in an Einstein universe that is rotating about some axis. If you were on the axis, you could remain at the same point of space, just as you do when standing at the center of a children's carousel. But if you were not on the axis, you would be moving through space as you rotated about the axis. The further you were from the axis, the faster you would be moving. So if the universe were infinite in space, points sufficiently far from the axis would have to be rotating faster than light. However, because the Einstein universe is finite in the space directions, there is a critical rate of rotation below which no part of the universe is rotating faster than light.

Now consider the sum over particle histories in a rotating Einstein universe. When the rotation is slow,



Thanks to the concept of warped spacetime, a time-traveling spacecraft could present the paradox of returning to port before it began its journey.

there are many paths a particle can take using a given amount of energy. Thus the sum over all particle histories in this background gives a large amplitude. This means that the probability of this background would be high in the sum over all curved spacetime histories — that is, it is among the more probable histories. However, as the rate of rotation of the Einstein universe approaches the critical value, so that its outer edges are moving at a speed approaching the speed of light, there is only one particle path that is classically allowed on that edge, namely, one that is moving at the speed of light. This means that the sum over particle histories will be small. Thus the probability of these backgrounds will be low in the sum over all curved spacetime histories. That is, they are the least probable.

What do rotating Einstein universes have to do with time travel and time loops? The answer is that they are mathematically equivalent to other backgrounds that do admit time loops. These other backgrounds are universes that are expanding in two space directions. The universes are not expanding in the third space direction, which is periodic. That is to say, if you go a certain distance in this direction, you get back to where you started. However, each time you do a circuit of the third space direction, your speed in the first or second directions is increased.

If the boost is small, there are no time loops. However, consider a sequence of backgrounds with increasing boosts in speed. At a certain critical boost, time loops

will appear. Not surprisingly, this critical boost corresponds to the critical rate of rotation of the Einstein universes. Since the sum-over-histories calculations in these backgrounds are mathematically equivalent, one can conclude that the probability of these backgrounds goes to zero as they approach the warping needed for time loops. In other words, the probability of having sufficient warping for a time machine is zero. This supports what I have called the Chronology Protection Conjecture: that the laws of physics conspire to prevent time travel by macroscopic objects.

Although time loops are allowed by the sum over histories, the probabilities are extremely small. Based on the duality arguments I mentioned earlier, I estimate the probability that Kip Thorne could go back and kill his grandfather as less than one in ten with a trillion trillion trillion trillion zeroes after it.

That's a pretty small probability, but it corresponds to the faint possibility that some bastard from the future came back and killed his grandfather.

As gambling men, Kip and I would bet on odds like that. The trouble is, we can't bet each other because we are now both on the same side. On the other hand, I wouldn't take a bet with anyone else. He might be from the future and know that time travel worked.

You might wonder if this scenario is part of a government cover-up on time travel.

You might be right.

A

Theoretical physicist Stephen Hawking is known for bringing complex cosmological physics to the general reader.

Anyone can sell you a telescope.

Authorized
Meade
Meade
Meade
Dealer



Hardly a day goes by that we don't get a note or E-mail message like the one reprinted on the next page, or a call that goes something like this: "Your ads are right. Dealer so and so advertises low prices – but they don't have what I want in stock, they couldn't answer any of my questions, and they wanted my credit card number before they'd even talk to me. They said if I wanted to ask questions, I should call the manufacturer . . . and then they hung up on me!"

If you want the right telescope, you need more than a camera store clerk armed with only a price list and a puzzled look when you ask questions.

What you *really* need are people who take the time to listen to what you need, people who answer your questions truthfully, people with years of experience

using and selling telescopes who help you get the most telescope for your dollar. That's exactly the kind of people you'll find at **astronomics**.

Unlike camera stores and shopping mall gift shops, telescopes are our specialty at **astronomics**, not just a sideline. We're a family-owned full-line telescope dealer – not just a few toy telescopes stuck off in the corner of some no-help department store, toy store, or gift shop as an afterthought. And, unlike department store clerks, we don't work on commission, so we won't try to sell you more than you need just to pad our paychecks.

We've been helping people choose the right telescope since 1979. We have the experience to help you pick the scope that fits your needs . . . and your budget . . . from the many Meade, Celestron, TeleVue, Takahashi, and Questar telescopes we stock at discount prices from \$99 to \$27,995.

And we can usually ship your right telescope right away, since we have over 1000 telescopes in stock!

astronomics. No hard sell. No guesswork. Just honest advice, the *right* scope, and a good price. Call us at (405) 364-0858 and find out for yourself.

Losmandy mounts are in stock.

If you're looking for a premium quality German equatorial mount, look no further than the Losmandy GM-8 and G-11 mounts we stock. They have adjustable height tripods and dual axis drives with PEC drive correctors. There are optional adapters available to fit virtually any catadioptric or refractor optical tube, plus the Losmandy accessories to customize the mount to your heart's content. We even stock go-to mounts and Gemini go-to retrofit kits.

TMB triplet apos!

Dozens of TMB refractors are in the hands of some very delighted customers of ours, and the buzz about them grows and grows. Visit our website to see the scopes that are the talk of experienced astronomers everywhere.

TMB 80/6 80mm (3.1") f/6	\$1390 ⁰⁰
TMB 80/7 80mm (3.1") f/7	\$1390 ⁰⁰
TMB 100 100mm (4") f/8	\$3290 ⁰⁰
TMB 105 105mm (4.1") f/6.2	\$3290 ⁰⁰
TMB 152 152mm (6") f/7.9	\$6990 ⁰⁰
TMB 175 175mm (7") f/8	\$11,990 ⁰⁰
TMB 203 203mm (8") f/9	\$19,990 ⁰⁰
TMB 254 254mm (10") f/9	\$39,995 ⁰⁰

Custom-built Dobs.

Astronomics offers custom-made truss tube Dobsonians hand-crafted by Pete Kron, a long-time Astronomics customer who is now a full-time member of our staff. Pete has been custom-building Dobs for over 15 years, in sizes up to a 36" f/5, and is known for his exacting quality standards. While Pete specializes in 18" through 24" apertures, custom mirror sizes and focal ratios are also available. He can also upgrade your unwieldy commercially-made Sonotube Dobsonian to an easily transportable truss tube version.

Prices start at \$3500 for a custom-built 18" scope. Converting your commercially-made Sonotube Dob optics to a truss tube mount starts at \$1500 for a 16" f/4.5 scope.

For more information, or to discuss specific pricing, contact Pete via e-mail care of questions@astronomics.com, or by phone toll-free from 9 to 5 Monday through Friday at (800) 422-7876.

Our free catalog helps you pick the right Celestron, Meade Questar, Stellarvue, Takahashi, TeleVue, or TMB scope.

For detailed information on individual products, visit our Web site. You can call us at (405) 364-0858, or e-mail us, for your free copy of our catalog AST. It covers all the scopes and accessories we stock – from Bushnell, Canon, Celestron, Coronado, Discovery Telescopes, JMI, Losmandy, Lumicon, Meade, Nikon, Parallax Instruments, Pentax, Questar, Rigel Sys-

Meade LX55 scopes make other reflectors and refractors obsolete.

For little more than the cost of an ordinary equatorial refractor or reflector, you can get a fully computerized Meade LX55. The go-to capability of the LX55 series is the most significant advance in an affordable German equatorial mount since the mount was invented in the early 1800s!

You won't spend your time hunting for faint deep space objects with a 5" or 6" LX55 refractor or a Schmidt-Newtonian 6" to 10" reflector. A few touches on the keypad of the built-in Autostar computer sends your scope speeding to any of the more than 30,000 stars and objects in its memory, centers it on the object, and tracks it while you observe. For many people, star hopping will become obsolete. You'll spend more

time looking at deep space objects and planets and less time looking for them with an LX55.

The scopes are complete with adjustable height tripod, motor drives, accessory tray, finder, eyepiece, and Autostar computer. Order now to get your German equatorial mount observing out of the dark ages.

TeleVue scopes are in stock (as is everything else TeleVue).

We have all the TeleVue scopes in stock, and in depth. Just look at this selection . . .

NP-101, standard package	\$3385 ⁰⁰
Renaissance-102, standard pack	\$2935 ⁰⁰
TV-102, standard package	\$2635 ⁰⁰
TV-102, optical tube only	\$2200 ⁰⁰
TV-85, standard package	\$2080 ⁰⁰
TV-85, optical tube only	\$1680 ⁰⁰
TV-76, standard package	\$1675 ⁰⁰
TV-76, optical tube only	\$1275 ⁰⁰
Pronto, standard package	\$1120 ⁰⁰
Pronto, optical tube only	\$775 ⁰⁰
Ranger, standard package	\$695 ⁰⁰
Ranger, optical tube only	\$570 ⁰⁰

Whether it's the newest telescope or the newest eyepiece, if it's from TeleVue, chances are good we have it in stock. Gibraltar, Panoramic, and TelePod mounts; Nagler, Radian, Panoptic, and Plössl eyepieces; Powermates and Barlows; red dot finders; 99% reflectivity Everbrite diagonals; 35mm and digital camera adapters; and more – we have it all. We're TeleVue specialists, and we stock TeleVue in depth. Call us and see.

The Stellarvue refractor, "Hot New Product of 2001."

The 80mm f/6 Stellarvue AT1010 was named a "Hot New Product of 2001" in the December 2001 *Sky & Telescope*. Independent reviews say it competes favorably with ED scopes that cost twice its modest price, and easily outperforms imported achromats in color correction and resolution. The AT1010CN has hand-assembled and triple

tested optics, tube rings, a 2" focuser with T-threads and 1.25" adapter, red dot finder, over-size upgraded rubberized focus knobs for easier use in cold weather, and a soft padded carry case. It's in stock to ship now.



NP-101 \$3385

TV-85 \$2080

AT1010CN \$499⁹⁵

shown optional diagonal and eyepiece

Fuji astro binoculars!

Comet Hyakutake, among others, was discovered using 150mm Fujinon binoculars. We can't guarantee that you will discover a comet with a 10 x 70mm or 16 x 70mm Fujinon FMT-SX binocular, but we can guarantee that the 70mm Fujinons are built to the same premium optical quality standards as the big Fujis. For pricing and full specifications, see our website at www.astronomics.com.

We stock Pentax XL eyepieces from \$227⁵⁰.

From 5.2mm to 40mm, we stock all the Pentax wide field (55° to 65°) XL eyepieces. Each has a rotate-to-adjust-the-eye-relief eyecup, ED glass, and a long 20mm eye relief that's perfect for those who wear eyeglasses.

5mm 1.25"	\$244 ⁵⁰
7mm 1.25"	\$237 ⁵⁰
10.5, 14, 21, or 28mm 1.25"	\$227 ⁵⁰
40mm 2"	\$244 ⁵⁰
8-24mm zoom 1.25"	\$379 ⁰⁰

Over 1,000,000 people a year visit our website for reliable information, helpful features, and secure on-line shopping.

www.astronomics.com

We stock Lumicon light pollution filters . . . the deep sky standard.

If city lights are blocking your view of the heavens, get rid of the light pollution with one of the many Lumicon nebula filters we stock. All are available in 1.25", 2", and rear cell versions for SCT use. We also have two-filter sets in various combinations at money-

saving package prices.

Deep Sky: broadband filters for visually and photographically observing nebulas from moderately light-polluted areas.

UHC: ultra high contrast filters centered on the H-Beta and Oxygen III lines for visual

use in badly light-polluted areas.

Oxygen III: visual line band for emission nebulas from badly light-polluted areas.

H-Beta: Horsehead Nebula line band for visual use from all light-polluted areas, as well as at dark sky sites.

astronomics

Our 23rd year of friendly service, good advice, and money-saving prices.

680 SW 24th Avenue, Norman, OK 73069

Toll-Free Order Line: (800) 422-7876

Catalogs/Questions/Advice: (405) 364-0858

We'll sell you the *right* telescope.

The Meade LX90 is in stock (45 of them on 1/10).

You can live the good life of big-aperture go-to full-featured fully computerized astronomy for not very much money with the 8" Meade LX90 Schmidt-Cassegrain.

The LX90 is only \$1695, including an adjustable height field tripod and a go-to Autostar computer with 30,223 stars and objects in its data base. Battery-operated, with a big 8 x 50mm finder and a 26mm Super Plössl eyepiece, it's ready to observe as soon as you receive it.

With LX90s arriving regularly (we had 45 in stock as this was written on



Meade LX90
\$1695

1/10), chances are good you can get your LX90 with little or no delay. If Meade is shipping the LX90 (or any Meade scope) for a dealer to keep in stock, the chances are very good that we have it in stock.

Meade prices are about the same anywhere you call. So why order a Meade scope or accessory from a dealer who charges your credit card, then makes you wait and wait until he finally gets around to ordering what you want? Not when you can usually get the Meade you want ... right now ... at the right price ... right here at **astronomics**.

Half-price observing books!

We bought almost 4000 observing books at some very special prices. We're passing our savings on to you, pricing them as low as 50% off retail. Take a look ...

Beginner's Guide to Amateur Astronomy 166 page soft cover, a great way to start, reg. \$14.95 ... **\$9⁹⁵**
Galaxies & The Universe 112 page soft cover, helps you find 100s of galaxies, reg. \$19.95 ... **\$9⁹⁵**
Stars & Galaxies 200 page hard cover, observe 344 of the best deep sky objects, reg. \$29.95 ... **\$14⁹⁵**
Universe From Your Backyard 188 page hard cover, observe 690 deep sky objects, reg. \$29.95 ... **\$14⁹⁵**

The 8" and 11" NexStar GPS are available from stock.

Celestron's go-to computerized scopes – the 11" NexStar 11 GPS at \$2999 and the 8" NexStar 8 GPS at \$2499 – were the first to use GPS technology to help you find your way around the sky. They use GPS (Global Positioning System) satellites and a built-in electronic compass to align themselves on the sky and locate over 40,000 deep sky objects for you ... *virtually automatically!*

For CCD imaging, both have Fastar-compatible optics that convert to ultra-fast f/1.9 and f/2.1 focal ratios for wide field images. With an optional Fastar lens and a \$1295 SBIG ST-237A CCD camera, the 8" GPS will record a huge 32 x 42 arc minute field – over three times the area of a \$7695 camera on the same scope without Fastar! No other GPS scopes have Fastar optics!

We have over 25 tons of telescopes in stock!

We generally keep over 1000 telescopes in stock. At a weight of more than 50 lbs. each, that means we usually have well over 25 tons of telescopes in inventory at any given time. We don't know of many dealers – if any – who stock telescopes in those quantities ... *no matter what they claim*. But we

do. And we don't just stock telescopes in large quantities. We have literally tons of accessories, as well. Eyepieces, filters, CCD cameras, dew caps, Barlows, off-axis guiders, electric focusers, T-rings, T-adapters, tele-extenders, counterweights, and more. Plus binoculars and spotting scopes, too.



6" f/8 DHQ, shown with optional eyepiece rack
\$299

Discovery Dobsonian reflectors start at only \$299.

Why settle for an imported Dob when you can have made-in-the-USA quality for *less money*? Discovery doesn't use imported, mass-produced optics that are merely spot-checked to see if they're acceptable. Discovery optics are made in California by optical craftsmen, one quality mirror at a time. Each is hand figured to diffraction-limited performance, and it doesn't leave the Discovery optical shop until it's right.

Each DHQ series Dob has an adjustable metal primary mirror cell, a true thin vane adjustable 4-vane diagonal mirror spider, two Plössl eyepieces, a built-in tube balancing system, a tube carry handle, new oversized bearings, a 6 x 30mm finder, and a dust cover. You can get an upgrade kit that adds two more

Plössl eyepieces, an eyepiece rack, a second dust cover, and a Moon filter for only \$49 more!

Premium Dobs from 10" to 17.5" in aperture are also available. And for those who need big aperture portability, truss-tube Dobs are available in apertures from 12" to 24". Here are the Discovery 6" to 10" DHQ Dob prices:
6" f/5 Discovery DHQ \$299⁰⁰, plus \$49 freight
6" f/8 Discovery DHQ \$299⁰⁰, plus \$49 freight
8" f/6 Discovery DHQ \$399⁰⁰, plus \$49 freight
8" f/7 Discovery DHQ \$399⁰⁰, plus \$49 freight
10" f/4.5 Discovery DHQ \$599⁰⁰, plus \$69 freight
10" f/5.6 Discovery DHQ \$599⁰⁰, plus \$69 freight

The new Meade GPS scopes.

You do the looking. They do the work.



Meade LX200 GPS
\$2495

Never before have so many features been packed into one telescope series. And never before have big aperture go-to scopes been so easy to use. The new LX200 GPS scopes – the widest variety of go-to telescope sizes and focal ratios on Earth – have the features you've dreamed about since you started astronomy.

Fully automatic GPS alignment, with true north and true level sensors and automatic magnetic declination correction; a unique mirror lock to eliminate image shift during critical CCD imaging sessions; a standard equipment 4-speed electric focuser; a built-in computer database of over 125,000 stars and objects; flashlight battery operation; and much more.

The Meade GPS scopes are designed to let you spend more time looking at celestial objects and less time looking for them. And isn't that what you want out of a telescope? Chances are good we have your personal Meade GPS scope in stock.

Canon image-stabilized binoculars for shake-free hand-held observing!

"Truly a quantum leap in binocular observing ... particularly impressive was how well these binoculars compared to much larger apertures ... " is what *Sky & Telescope* said about the Canon image-stabilized binoculars.



We have 61 SBIG CCD cameras in stock.

We stock almost all Meade and SBIG CCD cameras and auto-guiders. We also carry a wide range of CCD accessories – flip mirrors, off-axis guiders, color filter wheels, image processing software, and more. Our large inventory of CCD equipment (61 SBIG cam-

eras alone as this was written, 20 SBIG color filter wheels, 24 FR237 focal reducer/eflenders for the 17 STV and STVD cameras in stock, 8 SBIG adaptive optics systems, and dozens of SBIG accessories) means the chances are good that you won't have to wait to get the SBIG camera or accessories of your choice.

Canon that's right for you ... at new lower prices from Canon, too. You'll find full details and specs on our website.



Is a Questar a bargain?

If you only compare prices – a 3.5" Questar that starts at \$4050 versus the best-selling 3.5" Maksutov at \$495 – the answer is no.

But if you want world-class optics and the ultimate personal telescope, and have a very large discretionary income, a Questar for only \$4050 can seem like a bargain indeed.

Compare Celestron go-to prices. Only \$1499 for an 8" ...

Compare the price of the Celestron NexStar 8 go-to SCT with other 8" go-to scopes. At only \$1499 – complete with adjustable height tripod, Starbright multicoated optics, red dot finder, 40mm Plössl eyepiece, and a computer with 18,000+ objects in its memory – it's priced hundreds of dollars less than other 8" go-tos. It's enough telescope to keep you busy observing for the rest of your life, at a price that puts 8" go-to astronomy within the reach of practically anyone!

\$1149 for a 5" ...

You get a \$149 value adjustable height aluminum tripod (with built-in equatorial wedge) and a computer control for free when you buy a Celestron NexStar 5 go-to Schmidt-Cassegrain. Compare the price with the price of



NexStar 5

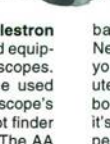


other 5" go-to scopes (including a tripod and computer) and you'll see that Celestron saves you nearly \$50. NASA uses 5" Celestron optics on the Space Shuttle. Don't you deserve the same premium image quality?

\$1149

\$599 for a 4" ...

The 4000-object computer of the Celestron NexStar 4 go-to Maksutov is standard equipment, not an option as it is with some scopes. The computer's hand control can be used even when docked conveniently in the scope's sleek single fork arm mount. A red dot finder makes aligning on the skies a snap. The AA



NexStar 4

battery-operated tabletop NexStar 4 is so easy to use that you'll be observing only minutes after you take it out of the box. At only \$599, complete, it's almost \$200 less than competitive 4" go-to Maksutovs.

\$599

A \$450 binocular for only \$179⁹⁵!

We bought 400 of the Celestron/Tasco 8 x 42mm \$450 list roof prism binoculars at a great price that lets us sell them for \$70 below dealer cost. Plus, you get a \$7.95 Nikon Lens Pen optics cleaning tool as a bonus.

Armored, waterproof, multicoated, BaK4 prisms, soft case, wide neck strap, 6.6° field, 16mm eye relief, and a **No-Fault** lifetime Tasco warranty! If they ever break, send them to Tasco with \$10 for handling and they'll be repaired or replaced for free!



I just wanted to thank you for the prompt attention you gave to my recent order. It is a real joy to do business with a company that obviously goes the extra mile to provide excellent service to customers.

Customer Quote of the Month #121

24-Hour FAX line: (405) 447-3337

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Our multiple award-winning Internet address: www.astronomics.com

Our phone lines are open 10 to 6 CST, Monday thru Friday, and most Saturdays from 12 to 5.

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U. S. sales only.

No credit card surcharge. \$6.95 minimum freight. All returns less freight. Restocking fees apply to returns for credit and to merchandise returned used or damaged.

sky Show

april

The planets put on a parade.
by Martin Ratcliffe and Alister Ling

► All five “classical” planets are visible across the sky at the same time this month. Once Mercury climbs into visibility after mid-month, try connecting the heavenly dots from the sunset to glimmering Mercury, blazing Venus, rusty Mars, yellow Saturn, and bright Jupiter. Ancient peoples heralded such planetary alignments as momentous events. Even today, we amateur astronomers revel in those rare occasions when we can view all the naked-eye planets in a row.

Take this opportunity to introduce the solar system to your family and friends. Surprisingly, many people don’t realize that most of the planets are visible to the unaided eye, even from urban areas. It won’t be hard to pique astronomical curiosity among the uninitiated with such an awesome display of our celestial companions.

Because the solar system basically lies in a plane, otherwise known as the ecliptic, our edge-on view of the planets causes them to appear in a fairly straight line. It’s not often, though, that they’re in positions that show off the ecliptic as a string of bright, sparkling beads. A bonus this month is the chance to glimpse the other planets in the morning sky — making it possible to see all the planets in one night.

Flighty Mercury is a snap to find, once you know when and where to look. The window of opportunity to see this inner planet is only three weeks, so make sure you act on it. Start looking about 40 minutes after sunset, and use brilliant Venus as a guidepost. In the last week of April, Mercury is halfway from the horizon to our sister planet. With binoculars you can start as early as April 15 to sweep the horizon below Venus and a little to its right to spot Mercury in its best evening apparition of the year.

A magnificent sight at any time of day comes from witnessing the moon



slide in front of a planet. On April 16 Saturn disappears behind the moon in a daylight occultation for western North America, and more spectacularly at night in most of Europe. Check www.lunar-occultations.com for local information to help you observe this unforgettable event.

It’s time to say farewell to comet LINEAR WM1. We’ve been following it for half a year, but soon the dirty snowball will be visible only through big telescopes. Adding to this disappointment, no comets are currently expected to come within binocular range for the remainder of the year.

When Earth passes through a comet’s stream of dust, the result is often a meteor shower. If you keep your eyes on the night sky April 20, you should see a few swift streaks originating near the bright star Vega. The Lyrids hit a peak of 10 to 15 meteors per hour on the morning of April 22.

In the Northern Hemisphere the

The bright star Arcturus dominates the spring constellation Boötes. Bill and Sally Fletcher

brightest stars of the winter sky set in the west. On the other hand, increasingly milder evenings should allow for more leisurely looks at a wide variety of celestial wonders. Stare into the eyes of Hydra the Serpent and behold the scintillating star cluster M48 (NGC 2548). Gaze across the night sky and notice how the winter realm of clusters and gas clouds is merely a preamble to spring’s display of galaxies.

Reacquaint yourself with the season’s well-known guidepost stars; start with the Big Dipper asterism standing on its tail in the northeast, then “arc to Arcturus,” the pale-orange luminary above the eastern horizon. Continue by “spiking to Spica” and you’ll have traced out one of the main roadways in the sky. As the years pass, you’ll come to know the sky like your own neighborhood streets.

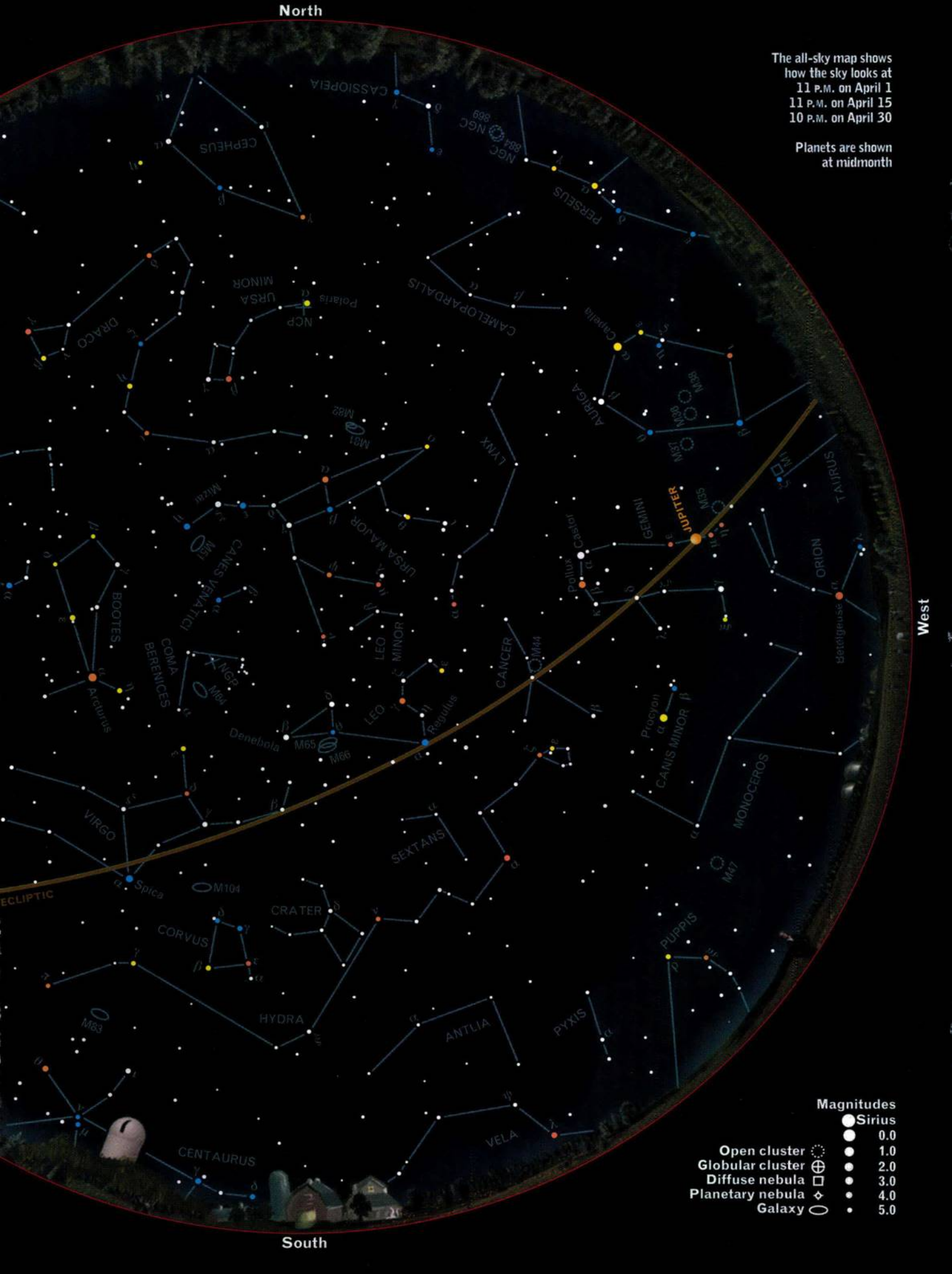
2002 April

- 4 Last quarter moon is at 10:29 A.M. EST
- 6 The moon passes 4° south of Neptune, 11 A.M. EST
- 7 Mercury is in superior conjunction, 5 A.M. EDT
The moon passes 4° south of Uranus, 9 P.M. EDT
- 10 The moon is at apogee (252,530 miles from Earth), 1:30 A.M. EDT
- 12 New moon is at 3:21 P.M. EDT
- 14 The moon passes 3° south of Venus, 1 P.M. EDT
- 15 The moon passes 2° south of Mars, 7 P.M. EDT
- 16 The moon passes 0.8° north of Saturn, 4 P.M. EDT
- 17 The moon passes 0.7° north of Vesta, 6 A.M. EDT
- 18 The moon passes 1.6° north of Jupiter, 7 P.M. EDT
- 20 First quarter moon is at 8:48 A.M. EDT
- 22 Lyrid meteor shower peaks (page 60)
- 25 The moon is at perigee (223,746 miles from Earth), 12:24 P.M. EDT
- 26 Full moon is at 11:00 P.M. EDT
- 29 Mars passes 6° north of Aldebaran, 9 A.M. EDT

SUN.	MON.	TUE.	WED.	THUR.	FRI.	SAT.
						
						
						
						
						

East

This map portrays the sky at times shown in the upper right corner of the page. Located just outside the map are the four directions: north, south, east, and west. To find stars above your horizon, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.



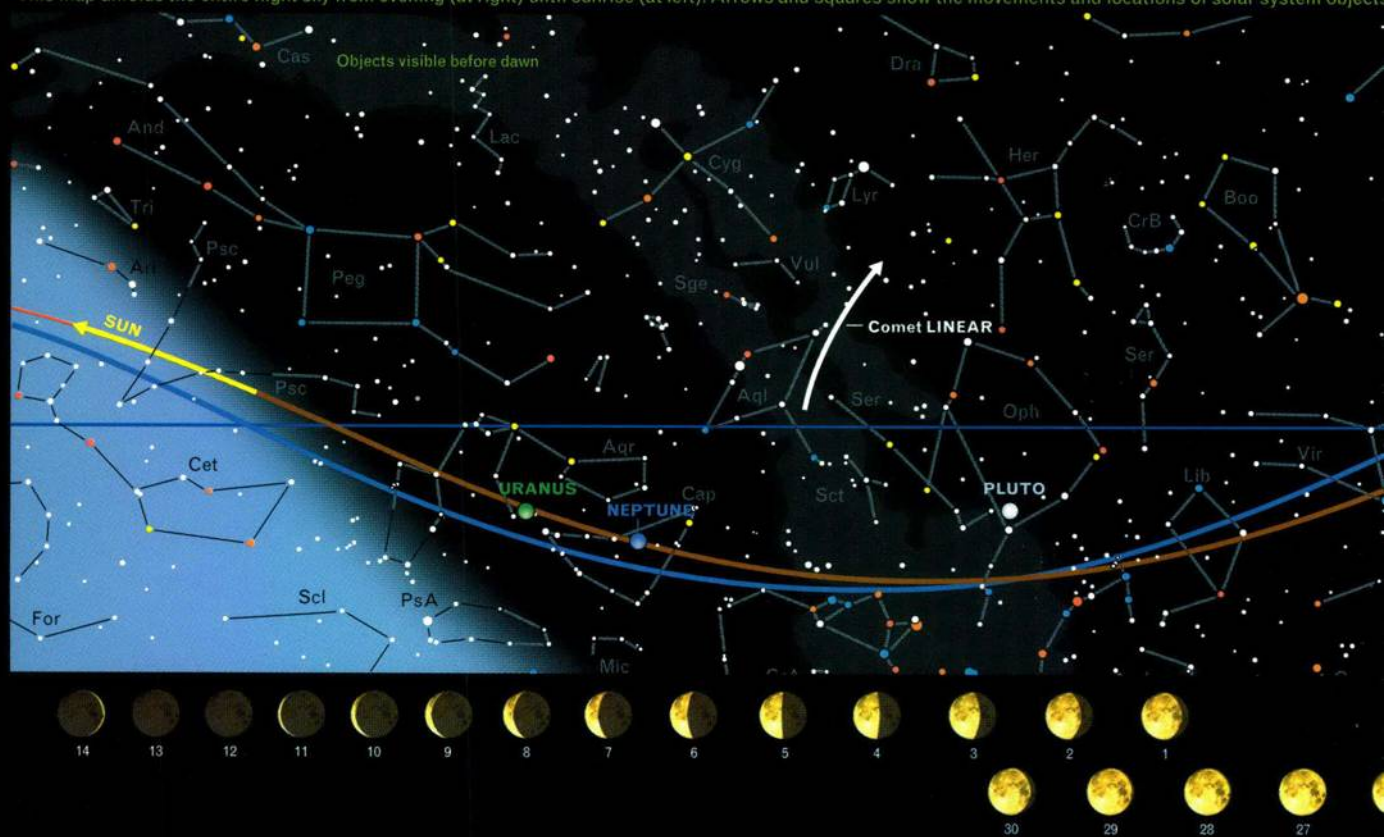
The all-sky map shows
how the sky looks at
11 P.M. on April 1
11 P.M. on April 15
10 P.M. on April 30

Planets are shown
at midmonth

- Magnitudes**
- Sirius
 - 0.0
 - 1.0
 - 2.0
 - 3.0
 - 4.0
 - 5.0
- Open cluster ○
Globular cluster ⊕
Diffuse nebula □
Planetary nebula ◇
Galaxy ○

Path of the Planets

This map unfolds the entire night sky from evening (at right) until sunrise (at left). Arrows and squares show the movements and locations of solar system objects.



PLANETS

Date

Magnitude

Angular Size

Illumination

Distance (AU) from Earth

Distance (AU) from Sun

Right Ascension (2000.0)

Declination (2000.0)

MERCURY

April 15

-1.6

5.3"

94%

1.264

0.309

2h03.6m

12°58'

MERCURY

April 30

-0.2

7.1"

50%

0.943

0.349

3h47.2m

22°32'

VENUS

April 15

-3.9

10.8"

93%

1.544

0.720

2h57.5m

16°55'

MARS

April 15

1.6

4.2"

96%

2.248

1.553

3h54.2m

21°01'

JUPITER

April 15

-2.1

36.5"

99%

5.400

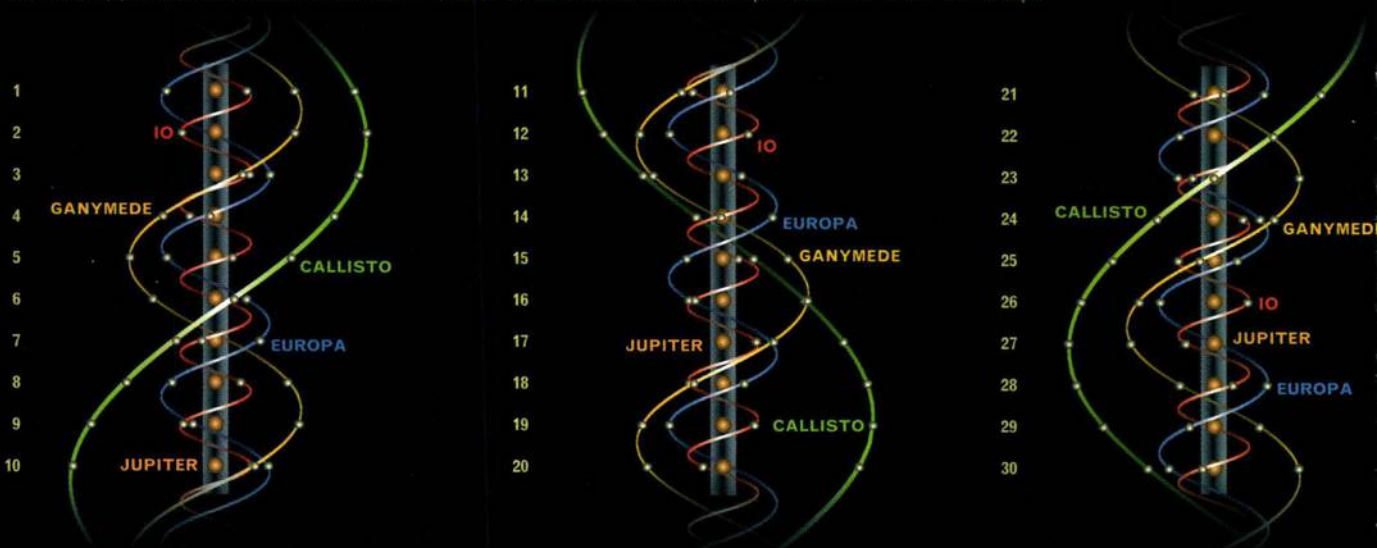
5.209

6h37.5m

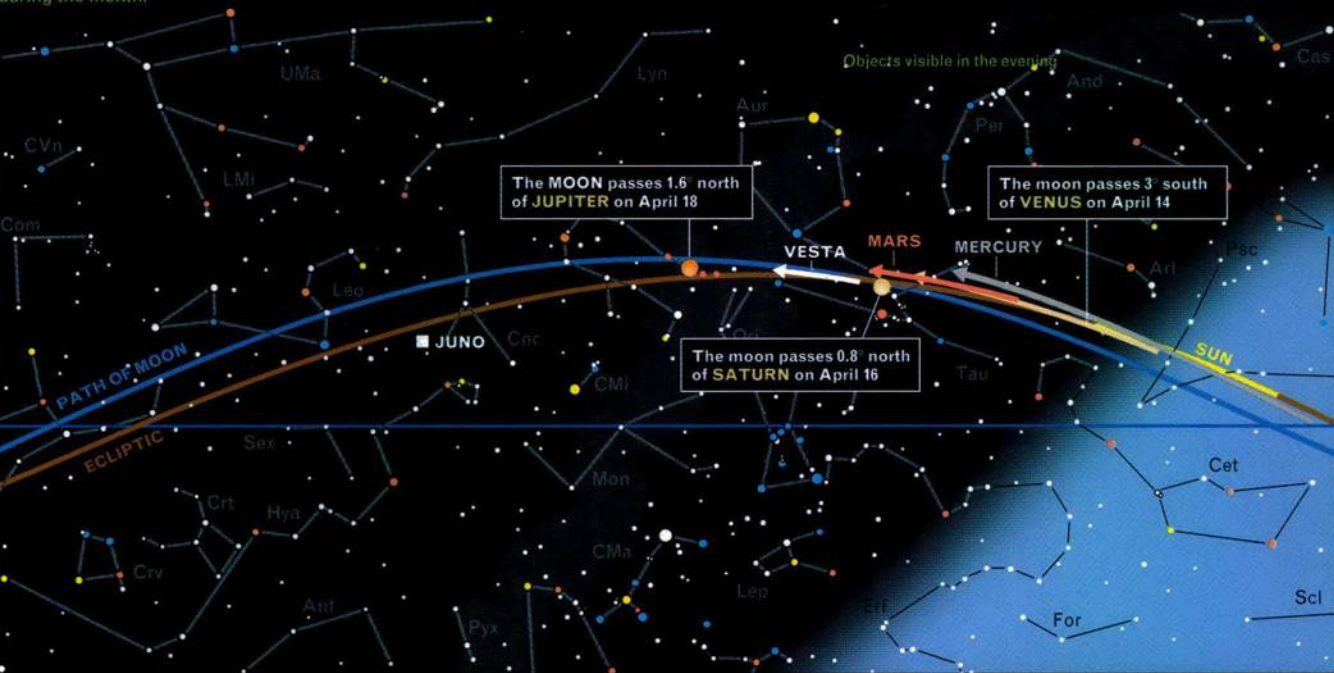
23°21'

Jupiter's Moons

Dots display positions of Galilean satellites at 11 P.M. EDT on date shown. South is at top to match the view in a telescope.



during the month.



To locate the moon in the sky, draw a line from the phase shown for the day straight up to the curved light-blue line.



R



SATURN

April 15
0.1
17.1"
100%
9.708
9.052
4h41.6m
20°48'



URANUS

April 15
5.9
3.4"
100%
20.525
19.996
22h01.2m
-12°53'



NEPTUNE

April 15
7.9
2.2"
100%
30.352
30.093
20h52.6m
-17°27'

.

PLUTO

April 15
13.8
0.1"
100%
29.888
30.498
17h09.2m
-12°48'



The Planets in Their Orbits

Arrows and dots show planets' positions during the month.



Hydra — Snaking Across the Sky

As if swimming against the river of time, Hydra the Serpent appears frozen in mid-slither across the southern spring sky. The circlet that forms its head is due east of Procyon, the bright yellow star above the western horizon on our foldout star map.

Hydra's head spans about 5° of sky — a perfect fit for most binocular fields of view. If you stretch out your arm and hold up your middle three fingers together against the background sky, they should cover just about 5°. People with bigger fingers tend to have longer arms, so this measuring trick works for both adults and children.

Unless you're a keen birder or an advanced amateur astronomer, chances are your first binocular view will be shaky. Try propping your elbows up on the roof of your car or leaning against a building to steady yourself. It's pretty easy to picture the four stars to the right as Hydra's head, and the star on the left as the beginning of its neck. Take a few moments to compare these stars to one other. Are they all the same color? Taking them slightly out of focus helps tease out the differences.

If you start at the head star to the far left, Zeta (ζ) Hydrae, and circle your way clockwise to the lower right, the stars gradually drop off in brightness from magnitude 3.1 to 3.4, and 4.1 to 4.5 (remember that the higher the magnitude, the fainter the object). If you can readily notice the difference between the magnitude 3.1 and 3.4 stars, then you have the skills to become a variable star observer. The top star of the head, Epsilon (ε) Hya, is a binary star. If you can push a 4-inch scope up to 150x, you should be able to spot its companion a mere 3" away — a little less than the size Mars appears right now.

Under dark rural skies, if you scan to the lower right about two binocular fields, you'll run into a hazy patch of light. This is the star cluster M48 (NGC 2548), discovered by French comet hunter Charles Messier more than two centuries ago. Even the smallest of spotting scopes should reveal a delightful splash of similarly bright stars,



arranged in chain-like patterns. Unlike some other star clusters, big-scope users often give M48 rave reviews too.

For 8-inch scopes under a dark country sky, a good challenge object lies smack in the middle of Hydra's head — the distant galaxy NGC 2644. At magnitude 13.1, its fuzzy oval form

Spot the open star cluster M48 amidst the splendor of Hydra the Serpent. Martin Germano

means you'll probably need to search for it with a modest magnification of at least 100x. At higher power, you may notice that the brightest area is a little offset from center.

Five naked-eye planets queue up in the evening western sky late this month. Such a spectacular procession of planets always draws attention — and *Astronomy* readers will be able to correctly identify each planet. The brightest is Venus, followed in order of decreasing brightness by Jupiter, Mercury, Saturn, and Mars. Since there are many changes in the planetary sky-scape in the coming weeks, let's start April 1 and closely follow the planets' movements throughout the month.

April opens with Venus, Mars, and Saturn stretched out over a 40°-long arc through Aries and Taurus. By the end of the month the three planets all lie within a 7°-wide circle and continue to close in on each other through May.

The planets come into view as dusk sets in; Venus is visible first because it glows the most intensely at magnitude -3.9 . Jupiter next breaks through the twilight standing 60° above the horizon and shines at magnitude -2.2 in Gemini. Saturn lights up the sky at magnitude 0.1 in Taurus. As twilight closes Mars pops out at magnitude 1.5. Later this month, Mercury shines at magnitude -1.1 low in the west, where it sets early in the evening.

Venus and Mars lie at opposite ends of Aries on April 1. Our sister planet sets soon after dark and climbs slowly higher each night. Watch Venus catch up to Mars during the month. On April 14 a new waxing crescent moon stands less than 4° away from Mars. By the next night, April 15, the moon sits just five moon-widths away from Mars, where the pair then lies less than 4° away from the Pleiades star cluster in Taurus. Grab a pair of binoculars to catch a breathtaking view of this stunning celestial grouping.

The following night, April 16, American observers will see the moon slide to the east of Saturn. Earlier in the day and farther east around the globe — in northern Europe, Britain and Greenland — skywatchers will see the crescent moon hide Saturn in one of a series of monthly occultations.

Jupiter welcomes the moon to its neighborhood in Gemini on April 18, when just three moon-widths separate

the huge planet from our lunar friend.

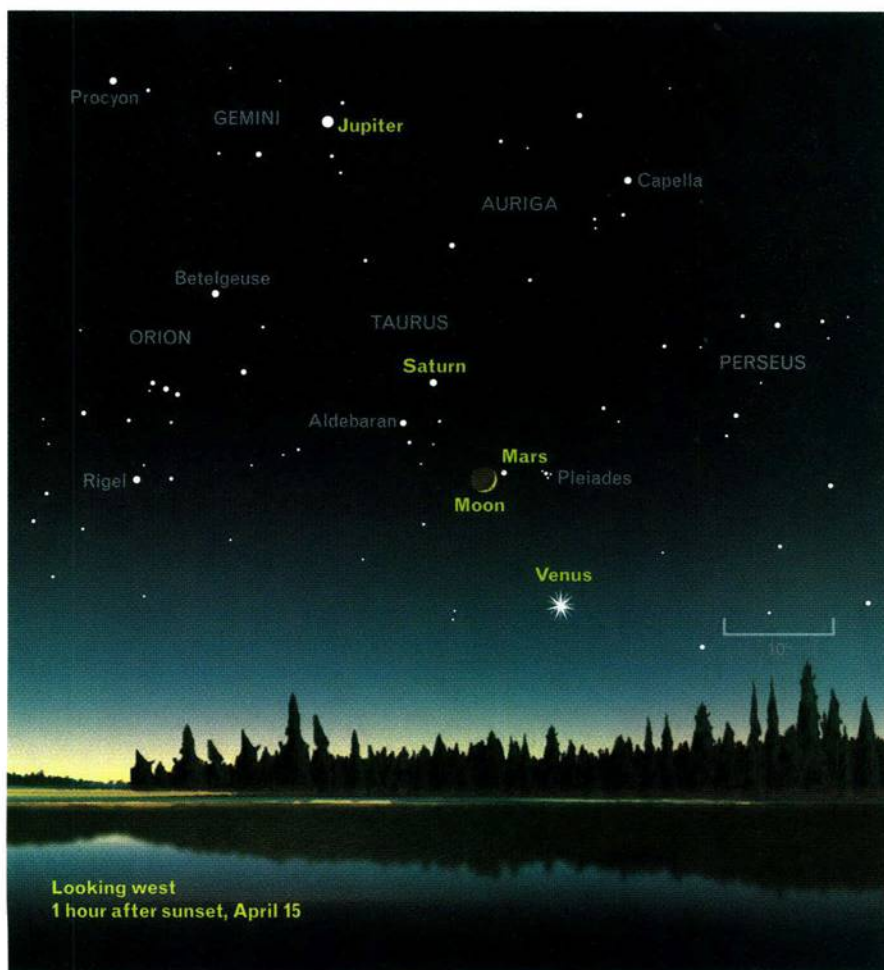
By the time the moon has made its elegant encounters with each of the four planets, Mercury joins the show following its superior conjunction with the sun on April 7. Late April marks Mercury's best appearance this year for observers in the Northern Hemisphere. Now five planets are visible every evening for an entire month. Mercury gradually floats higher in the west-northwestern evening sky during the latter half of the month.

By the evening of April 18 Mercury sets an hour after the sun and shines at a bright magnitude of -1.3 , just enough to burst through the twilight. Night after night Mercury seems to be playing catch-up with Venus — a game Mercury can never win.

Venus passes less than 4° south of the Pleiades star cluster on April 24.

And just five days later, Mercury passes less than three moon-widths south of the same cluster. The mercurial planet dims to magnitude -0.4 , and Venus moves in on Mars. In fact, Venus lies exactly midway between Mars and Mercury. The Red Planet is a dim magnitude 1.6, half a magnitude fainter than nearby Aldebaran.

By April 30 Mercury, Mars, Venus, and Saturn are strung out in a spectacular grouping in Taurus, where only 13° separates the four planets. Mercury sets two hours after the sun. As the group drops toward the western horizon, Aldebaran — the brightest star in Taurus — pops into view just 7° to the left of Venus. The V-shaped group called the Hyades adds depth to the spectacle. Saturn and Mars stand 5° higher than the Hyades and the pair is less than 3° apart. The planets' different



Looking west
1 hour after sunset, April 15

The Planets

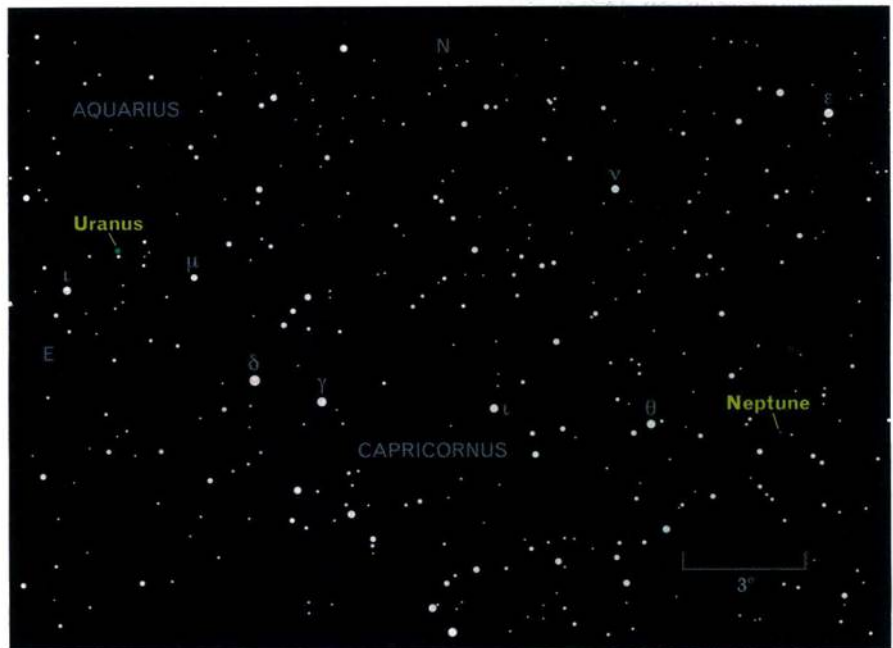
colors — a reddish Mars and a yellowish Saturn — should be noticeable.

The grouping of planets this month should prove the most photogenic such event to occur in the last few years. When mounted on a tripod, many digital cameras can capture excellent pictures of the sky. Regular, single-lens reflex cameras and film often take higher quality images. Use a standard lens set at its widest aperture and medium speed film (ISO 200 to 400), and bracket time exposures from 10 to 30 seconds. With just the right timing you'll catch the spectacular colors of late twilight. During mid-twilight, excellent silhouettes of trees and buildings in the foreground add greatly to the scene. Also, the occasional lenticular cloud will add some great depth to an image.

High above all this planetary intrigue stands Jupiter. During April, the mighty king of the planets traverses Gemini, ending the month located centrally in the constellation — a position it held last Christmas. Jupiter's face should reveal many features, thanks both to the size of its disk — the largest fully illuminated disk of any planet when viewed from Earth — and the violent turbulence in its distinctive atmosphere. Small telescopes should sight these curiosities. Only patience at the eyepiece reveals the more subtle spots and belts. Watch for any atmospheric changes over the next two months before Jupiter disappears behind the sun.

Wait until after midnight to view the three distant planets Uranus, Neptune, and Pluto. Pluto lies in Ophiuchus, 3° north of Eta (η) Ophiuchi, and reaches opposition on June 7, shining at magnitude 13.8. You'll need at least an 8-inch telescope and good sky conditions to spot our most distant planet from the sun.

Uranus and Neptune rise an hour apart, with Neptune appearing first. Neptune lies in Capricornus the Sea Goat, 3° west of Theta (θ) Capricorni. Uranus crosses into Aquarius the Water Bearer this month. It stands between three and four moon-widths northwest of Iota (ι) Aquarii.

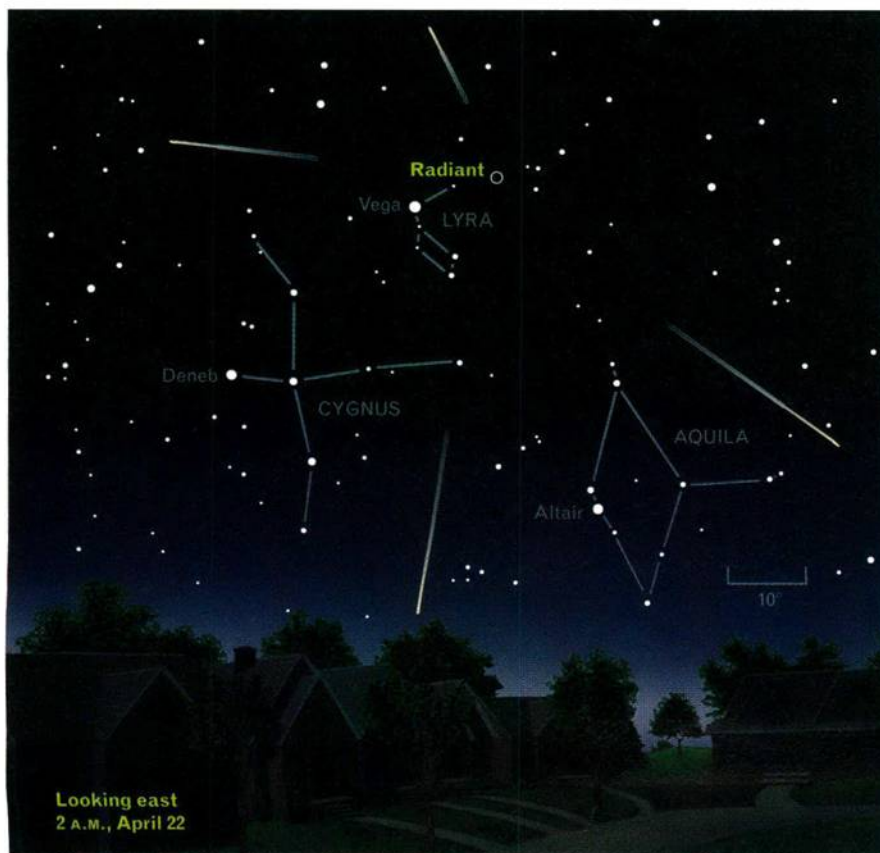


Looking west
1 hour after sunset, April 30

April Lyrids

The Lyrid meteor shower will appear to radiate from Lyra the Harp. Vega, the constellation's brightest star, rises in the northeast shortly after sunset. The peak of the shower occurs in the early morning hours of April 22 in the continental United States. This meteor shower produces moderate activity every year and should sustain between 10 to 15 meteors per hour in the predawn darkness. More active displays occurred in 1803, 1922, and 1982, during times when Earth crossed denser regions of the comet's debris trail.

A -4-magnitude Lyrid fireball shoots across the sky (far right) above California. George Zay



Looking east
2 A.M., April 22

Sirsalis and Rimae Sirsalis

Between one and two days before the full moon, the sun rises on the moon's overlapping craters of Sirsalis and Sirsalis A. This lunar locale gets its name from 17th century Italian moon-mapper Gerolamo Sirsalis (Sersale). The craters are located near the moon's western limb and south of the large walled plain Grimaldi. Since Sirsalis has broken the wall of Sirsalis A, it is clearly the younger of the two craters. Sirsalis is 27 miles wide with a small but prominent central mountain peak. Sirsalis A is three miles wider than its sibling. Under the sun's low illumination two days prior to the full moon you might spot the long rille

called Rima Sirsalis, which crosses more than 200 miles of the lunar terrain. How far can you trace it? Two small fresh craters break the rille just beyond the southern edge of Sirsalis. The multiple rille system found here is named Rimae Sirsalis — "rimae" is the plural form of "rilles" — and April 25 and April 26 are the best nights to view such features.

Jupiter's Satellites

Rare events involving occultations, transits, and eclipses of Jupiter's moon Callisto continue. During Jupiter's 12-year orbit of the sun, only two series of eclipses involving Callisto occur. The current series began last September and continues until September 2004 — a time span wherein 66 eclipses occur. Events listed here are given in Universal Time (UT, or Greenwich Mean Time) and Eastern Daylight Time (EDT). Events that occur on either side of midnight are shown twice*, since the date changes for observers in Europe or the United States.

IV stands for the moon Callisto; Tr = Transit; I = Ingress; E = Egress; Oc = Occultation; Sh = Shadow Transit; Ec = Eclipse; D = Disappearance; R = Reappearance. Not all events are visible from the United States.

Callisto Events for April 2002

	UT	EDT	
Apr. 7	11:18	7:18 A.M.	IV.Tr.I.
	14:22	10:22 A.M.	IV.Tr.E.
	23:09	7:09 P.M.	IV.Sh.I.
Apr. 8		10:46 P.M.	IV.Sh.E.*
	2:46		IV.Sh.E.*
Apr. 15	18:48	2:48 P.M.	IV.Oc.D.
	10:01	6:01 P.M.	IV.Oc.R.
Apr. 16	6:27	2:27 A.M.	IV.Ec.D.
	10:12	6:12 A.M.	IV.Ec.R.
Apr. 24	6:11	2:11 A.M.	IV.Tr.I.
	9:26	5:26 A.M.	IV.Tr.E.
	17:11	1:11 P.M.	IV.Sh.I.
	20:55	4:55 P.M.	IV.Sh.E.

Comets and Asteroids

There's a lot more to the solar system than the bright planets lining the evening sky. In excess of 30,000 space rocks orbiting our sun have been confirmed and catalogued. Typically, though, only a few dozen come within reach of a small scope from the average suburban backyard.

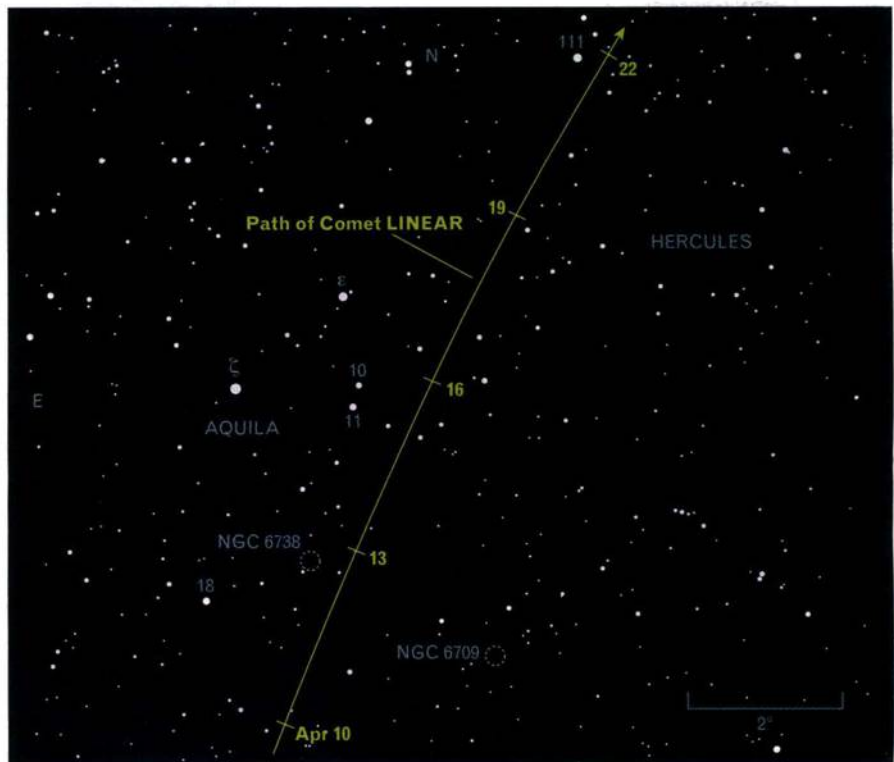
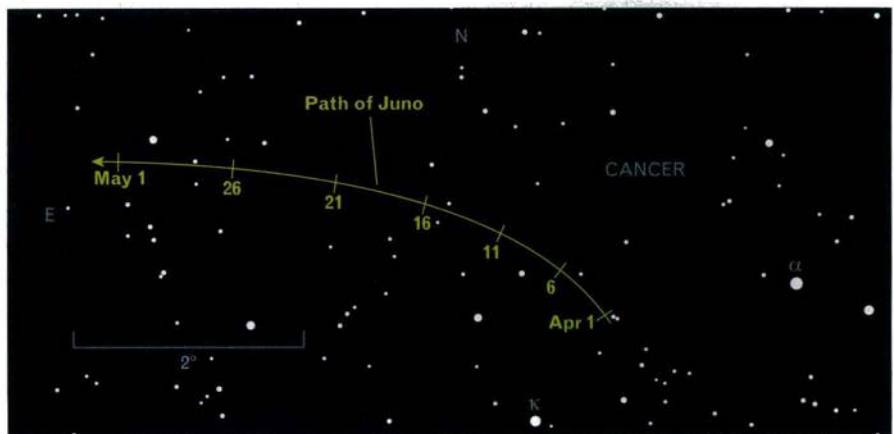
Juno was the third asteroid to be discovered, way back in 1804. At 150 miles (240 km) across, 3 Juno is the smallest of the "big four" asteroids that rule the rubble between the orbits of Mars and Jupiter. To find it, start at the head of Hydra (see the Deep Sky page), and jump north to Alpha (α) Cancri. From there, use the map (upper right) to slowly narrow in on its position.

At magnitude 9.5, Juno appears as a faint star through a small telescope. A number of background stars of similar brightness reside in the area, making identification of Juno slightly tricky. The tried and true method for targeting an asteroid like Juno is to make a quick sketch of the brightest stars in the field of view, then go back a night or two later to see which "star" has moved. Once you get used to a telescopic field, it's surprising how easy it is to follow an asteroid from one night to another without a chart.

Good-bye Comet LINEAR WM1

After reaching its peak in December, LINEAR WM1 now recedes into the depths of the Oort Cloud. This month may be your last chance to say "so long" to this streaking wonder. The window of opportunity for glimpsing this fuzzy snowball extends from April 10 to 22, when the moon is new or away from the morning sky. Since the comet is best seen before dawn, it will be easier to watch on the weekends of April 13 or April 20 — the latter is a good time to also glimpse the Lyrid meteor shower.

Telescopes of 6 inches or less will have trouble revealing much more than a small fuzz. If you've had a chance to check out a number of the spring galaxies in the Virgo Cluster, then you'll be in shape for comet LINEAR WM1. At 10th magnitude, the comet is similar in brightness to the trailing end of the Messier objects.



On the morning of April 13 the comet lies 35' (a bit bigger than our moon's angular size) to the west of the open star cluster NGC 6738 — a triangular group that stands out fairly well in the background. A little bit farther west and south lies NGC 6709, another lovely star cluster for small and large scopes alike. NGC 6709 sits in the region where David Levy discovered one of his comets.

As with all comets, examine LINEAR WM1 under a range of mag-

nifications. The comet should show a sharper eastern side and a more diffuse western flank. You can tell which side is west because it will be the first to slide out of the field of view when there is no drive on your scope. **A**

Martin Ratcliffe is president of the International Planetarium Society and observes from Wichita, Kansas. Alister Ling is a meteorologist working for Environment Canada.

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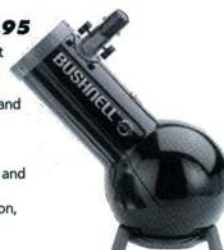
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Africa and Australia vie for visitors hoping



QUENCHING THE

SUN'S FIRE

by Richard Talcott

to see December's total eclipse of the sun.

A familiar yellow globe hangs in the sky each day, bringing us light and warmth. We curse the sun in summer when it seems too hot and again in winter for deserting us. Despite these complaints, we rely on the sun's familiarity and constancy, knowing that it will always be there, always looking the same.

Maybe that's why eclipses fascinate us so. For a few brief moments, the moon transforms this familiar sun into another object entirely. It's not some staid, yellow sphere, but a dynamic object with fiery red tongues of gas leaping from its surface and a ghostly atmosphere stretching far beyond the limits of what we typically see.

Veteran eclipse chasers often travel great distances for a fleeting view of our transfigured star. They know that the joy of experiencing totality outweighs the inconveniences, and eagerly anticipate any opportunity to stand in the moon's shadow, no matter how far they must travel. Many are already making plans to head south of the equator for the next eclipse, which will bring totality to a narrow swath of southern Africa and Australia on December 4, 2002.

Eclipse watchers don't have an easy choice in deciding which continent to visit. Africa offers a longer period of totality — two to three times greater than Australia — but Australia has a better chance of clear skies. Political and health considerations may also play a role in the decision. In the end, the best location may depend more on which region of the world you'd rather visit than on the eclipse specifics.

The moon's shadow first touches Earth at sunrise in the Atlantic Ocean, several hundred miles south of the coast of Ghana. Seven minutes later the umbral shadow — where the moon totally hides the sun's disk from view — reaches the coast of Angola, just south of Ngunza. If this region sounds familiar, it should: The path of totality during the June 21, 2001, eclipse crossed this exact same region. On average, a specific spot on Earth experiences totality about once every 300 years. With two total eclipses in a span of 18 months, the residents of coastal Angola surely beat the odds.

The moon's shadow then races southeast across Angola, eventually straddling the border between that country and Zambia. It then briefly sweeps across the narrow Caprivi Strip in eastern Namibia before diving into Botswana. There it plunges part of the renowned Chobe National Park into darkness. The shadow then follows the border between Botswana and Zimbabwe before entering southern Zimbabwe entirely.

While in Zimbabwe, the path of totality crosses Hwange National Park, a favorite destination for many 2001 eclipse visitors. The majestic Victoria Falls and Bulawayo, Zimbabwe's second-largest city, lie just north of the eclipse track and will see the moon cover 98 percent and 99 percent of the sun, respectively. When the shadow enters northern South Africa, it crosses Kruger National Park, the crown jewel of that country's park system. The track then traverses southern Mozambique before leaving the continent.

Two main factors distinguish the African portion of this eclipse from the June 2001 eclipse. First, the view of totality

will be a lot shorter this time. On the center line in 2001, the moon hid the sun for anywhere from three minutes to more than four minutes. In December 2002, totality increases from 50 seconds on the Angolan coast to 1 minute and 32 seconds in eastern Mozambique.

The weather may pose an even bigger concern. December marks the beginning of summer in the Southern Hemisphere — the wet season in southern Africa. Although not the height of the rainy season, December typically brings significant cloudiness and rain. Contrast that to the June 2001 eclipse, where the summer skies were brilliantly clear from coast to coast.

Statistics show that the worst weather prospects occur in western Angola, then improve gradually as the eclipse path marches east. Unfortunately, the wet season severely limits travel within Chobe National Park. Access to the eclipse track could be difficult even with a four-wheel-drive vehicle. Hwange National Park doesn't fare much better, and the center line passes through a remote part of the park that makes last-minute movement nearly impossible.

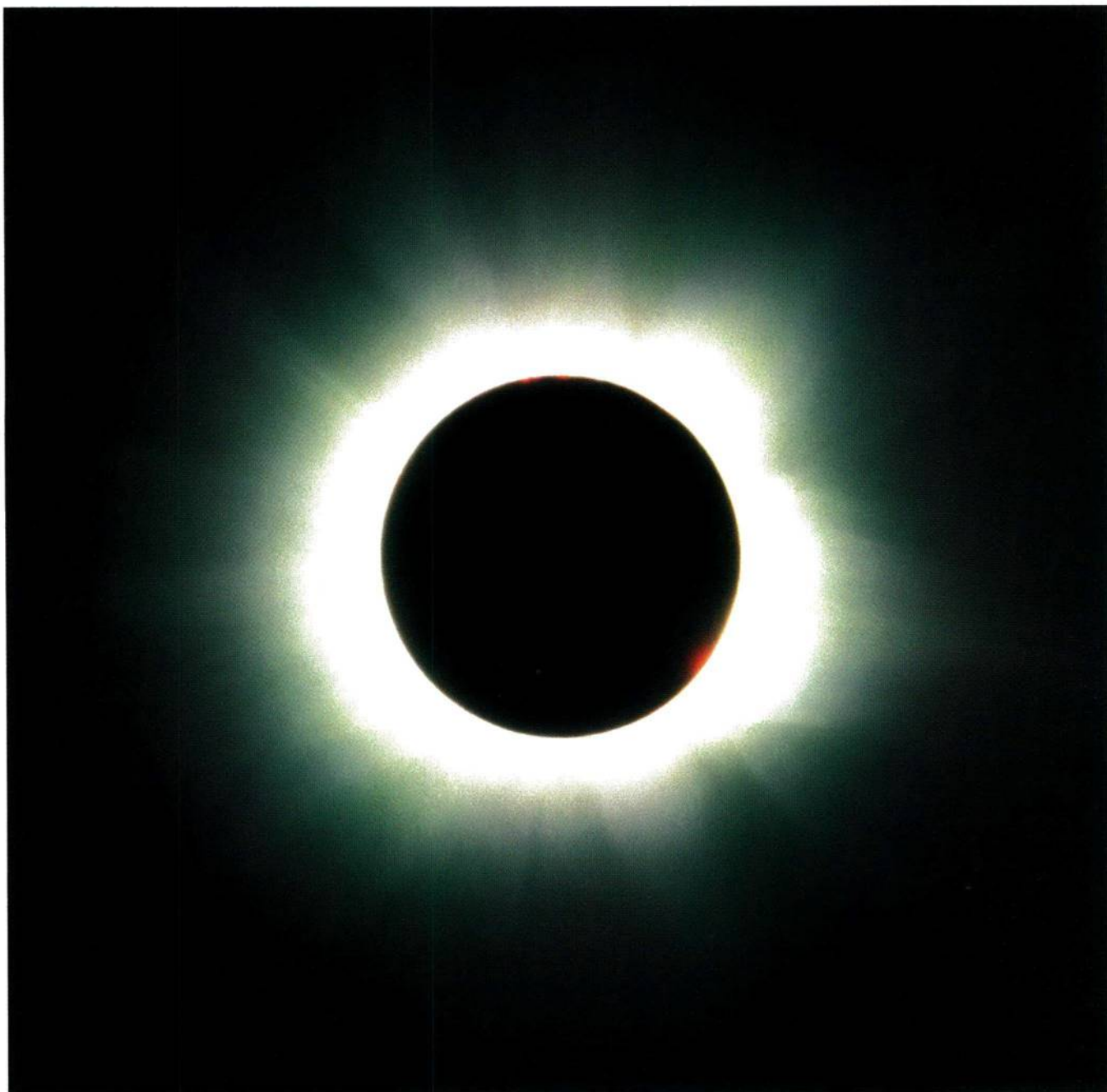
The best weather prospects in Africa run from southern Zimbabwe, near Beitbridge on the border with South Africa, to western Mozambique. Statistics show about a 50-50 chance of good weather, but you should be able to increase those chances by staying mobile.

Summer in southern Africa also means warm temperatures and high humidities. Expect afternoon highs typically near 90° Fahrenheit in the prime viewing area, with nighttime lows dropping to around 70° F. Although the muggy conditions may be uncomfortable, the flying insects can be downright dangerous. Summer brings with it a bumper crop of mosquitoes, and they're hungry. (Don't be lulled into a false sense of security by the few lethargic mosquitoes you may have seen in June 2001.) Malaria and other mosquito-borne diseases are common in the summer — be sure to wear light-colored clothing, slather on the insect repellent, and bring along antimalarial medicine.

The political situation adds a measure of uncertainty to any travel in southern Africa. Conditions range from excellent in Botswana to horrid in Angola. The U.S. State Department warns American citizens against visiting Angola, where a decades-long civil war still rages. Some of that conflict has spilled over into the Caprivi region of Namibia, making travel there inadvisable as well. The situation in Zimbabwe also seemed to be deteriorating as 2001 drew to a close. "War veterans" have occupied many commercial farms, and fuel shortages and street crime seem to be rising as the economy falters. What December 2002 may bring is anyone's guess. To keep up with the latest news throughout the region, check out the State Department's website at www.state.gov.

After leaving Africa, the umbral shadow begins a long journey across the Indian Ocean. Maximum eclipse occurs more than 1,000 miles southeast of Madagascar, where the

Lucky eclipse chasers in Africa and Australia will witness the diamond ring effect as the moon hides the sun in December 2002. Wesley Jacobs



sun disappears for 2 minutes and 4 seconds and the path measures 54 miles wide.

Just 90 seconds before the shadow lifts back into space, it touches land again in South Australia. It comes ashore at the small town of Ceduna, where the sun disappears for 33 seconds as it stands 9° above the ocean. From there it moves northeast, crossing the immense salt pan Lake Gairdner and then the southeastern corner of the Woomera Prohibited Area, a former weapons-testing site still used for rocket launches. It next heads just south of the uranium-mining town of Roxby Downs and on past the northern tip of the Flinders Range. The umbral shadow briefly kisses the northwestern corner of New South Wales before ending its 7,500-mile-long run in Queensland. On the center line at the end of the path, totality lasts 22 seconds.

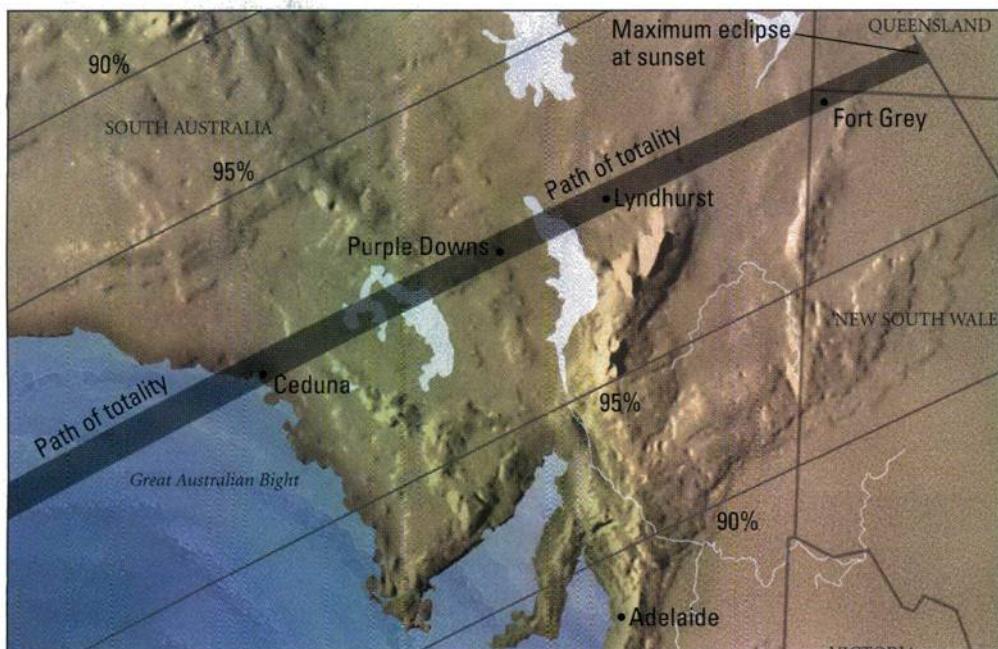
December ranks among the sunniest times of year in southern Australia; the level of cloudiness falls significantly

Above: Thousands of people headed to Africa in June 2001 to catch a glimpse of the sun's corona. Robert Slobins

Opposite page: At totality, a surreal effect appears as day turns to night for a few fleeting moments. Isaac and Heidi Kikawada

below that of Africa, which can be a big advantage. Unfortunately, the sun's low altitude at eclipse time lessens that advantage. (An observer has to look through a much larger amount of the atmosphere when the sun lies near the horizon, so even a little cloudiness can block the view.)

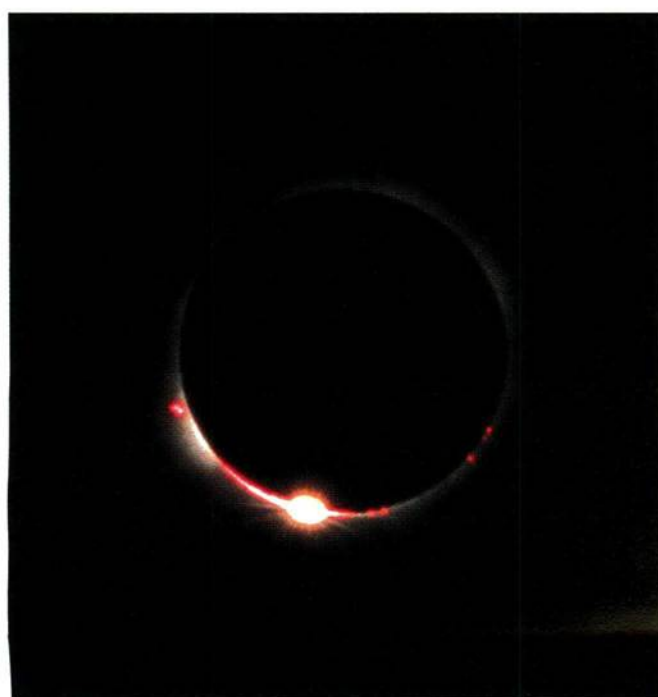
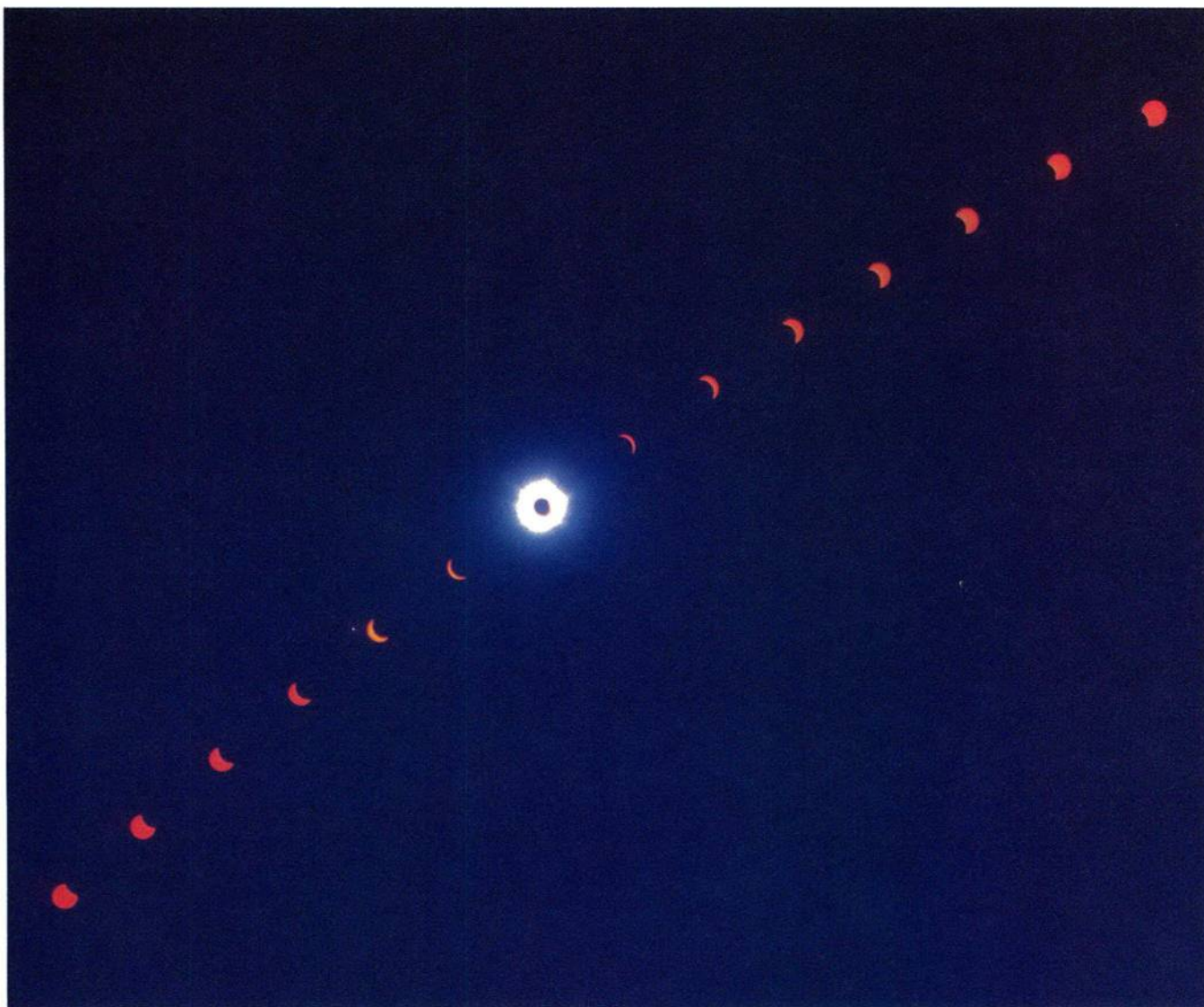
The coastal areas of Australia tend to be cloudier, with the arid interior offering on average twice as many clear days in December. An afternoon sea breeze may also complicate observations at Ceduna, where the winds exceed 20 miles per hour four out of every five days. That can jostle sensitive photographic equipment and telescopes, so consider inland sites if those are in your plans.



Along the Track

Location	Length of Totality	Local Time at Maximum Eclipse	Sun's Altitude	Sun's Azimuth	Chance of Decent Skies
Huambo, Angola	0m53s	6:58 A.M.	21°	109°	35%
Linyanti, Namibia	1m07s	8:08 A.M.	33°	105°	40%
Plumtree, Zimbabwe	1m16s	8:14 A.M.	38°	103°	55%
Beitbridge, Zimbabwe	1m22s	8:19 A.M.	41°	101°	60%
Shingwedzi, South Africa	1m26s	8:21 A.M.	43°	99°	60%
Chibuto, Mozambique	1m30s	8:26 A.M.	47°	97°	55%
Ceduna, Australia	0m33s	7:40 P.M.	9°	249°	55%
Purple Downs, Australia	0m28s	7:41 P.M.	6°	247°	65%
Lyndhurst, Australia	0m23s	7:41 P.M.	4°	247°	65%
Fort Grey, Australia	0m20s	8:12 P.M.	2°	245°	65%





Above: This eclipse composite shows the sun from first contact to the climax, the moment of totality. *Alberto Levy*

Left: Baily's beads appear just before and after totality, due to sunlight passing through valleys on the moon's surface. *Wesley Jacobs*

Weather statistics indicate that the chances of seeing the eclipse range from about 55 percent on the coast to 65 percent inland. That's a little better than the best Africa offers, but at a sacrifice of nearly a minute in totality. If you do venture into interior Australia, your biggest concern could be the heat. Daytime highs in December average in the mid-90s and records often hit 110° F. (And that's in the shade!) Be sure to wear a hat, drink plenty of water, and take frequent breaks.

Despite the disadvantages of the December 2002 eclipse, think twice about passing it up. The next total solar eclipse to make significant landfall doesn't arrive until March 2006. A total eclipse in November 2003 touches down only in Antarctica, while a rare annular-total eclipse in April 2005 in Central and South America doesn't touch land during totality. If you want to see the sun transformed within the next four years, best make your plans now for Africa or Australia. **A**

Richard Talcott is senior editor of Astronomy.

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Hydra



*Glittering star clusters
and striking galaxies vie
for your attention within
the boundaries of the
Water Snake.*

by Tom Polakis

As Orion and Puppis depart with their Milky Way treasures on spring evenings, the temptation is to settle into galaxy observing in Leo and Virgo. Yet the largest constellation in the sky — Hydra the Water Snake — lies sandwiched between these regions. Hydra's sheer size results in a constellation that hosts a diverse mix of interesting telescopic objects.

You can follow the form of Hydra's western half as it runs parallel to the Milky Way east of Canis Major. At the northern end, Hydra's head consists of five 3rd- and 4th-magnitude stars. To the southeast you'll easily spot Alphard (Alpha [α] Hydrae), the constellation's brightest star at magnitude 2.0. The yellow-orange star lies 177 light-years from Earth and shines with the light of 400 suns. From Alphard, Hydra traces a zigzag pattern before turning east to a more ill-defined line of stars south of Corvus and Virgo.

Our telescopic tour starts with **Epsilon (ϵ) Hydrae**, the northernmost star in the head of Hydra. A telescope at 150x splits this naked-eye star in two: a bluish 7th-magnitude secondary appears less than 3" west-northwest of the 3rd-magnitude primary. These stars complete one orbit every 990 years. Epsilon Hydrae also contains a third star, but this companion to the primary orbits once every 15 years and appears only 0.3" away at its farthest, making it impossible to resolve in backyard telescopes.

A little more than 10° southwest of Hydra's head lies **M48** (NGC 2548), an open star cluster faintly visible to the naked eye. Large binoculars resolve a couple dozen of its brightest stars, which scatter over 1° of sky. A tele-

scope reveals about 75 stars sprinkled across an entire low-power field. Increasing the magnification increases the star count, though the appearance of being a cluster quickly becomes lost. Look for a chain of ten 9th- and 10th-magnitude stars running roughly north-south through the cluster's center and extending some 10'.

In the southwestern corner of Hydra resides **NGC 2610**, a bright planetary nebula that responds well to a nebula filter. Find it by sweeping 4° southwest of the 4th-magnitude star 12 Hydrae. The planetary lies 8,000 light-years away and spans 0.75 light-year. In a 13-inch telescope at 300x, NGC 2610 appears as a uniformly bright circular disk about 40" across. A 12th-magnitude foreground star shines on the northern edge. Larger telescopes show NGC 2610 as a thick ring with an elusive central star.

Pan 10° northwest of Alphard to find **NGC 2708**, a small, bright galaxy involved in a modest group. At 200x in a 12-inch scope, NGC 2708 appears twice as long as it is wide, with its long axis oriented north-south. A stellar nucleus shines through the broadly concentrated center. To the northwest in a 1° field resides some two dozen galaxies, five of which are NGC objects visible in a large telescope. How many of these can you see?

Sweep 2° south of Iota (ι) Hydrae to find the large planetary nebula **Abell 33**. Your best chance to spot this faint emission object comes at low magnification while using a nebula filter. At 70x in a 12-inch scope, it shows an oval haze measuring 4' by 3' that hints at a thick ring structure. The inner region of the ring glows brighter than the sky surrounding the nebula, while



George Greaney

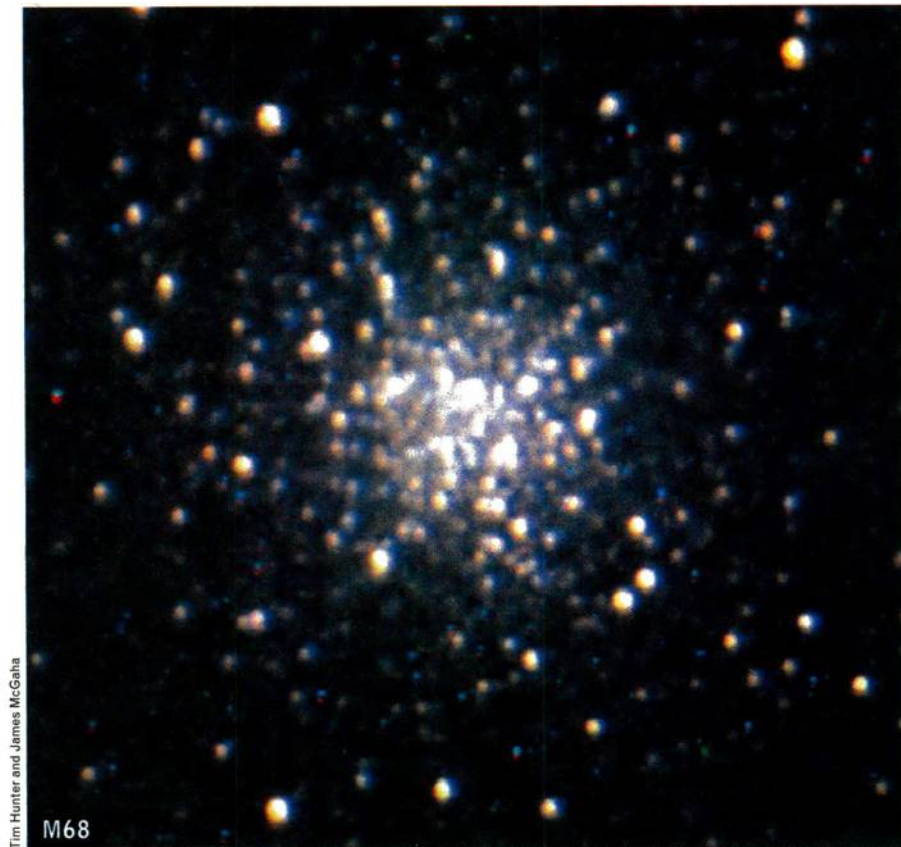
the central star comes into view faintly with the nebula filter removed. A 7th-magnitude star at the southern edge creates some glare.

Next head south to Hydra's border with Pyxis to locate the bright galaxy **NGC 2784**. An 8-inch telescope shows a very bright core surrounding an oval halo oriented roughly east-west. A faint star appears in front of the galaxy's northeastern edge.

One of the showpiece planetaries of the spring sky can be found 2° south of 4th-magnitude μ Hydrae. **NGC**

3242, also known as the Ghost of Jupiter, glows brightly and yields well to high magnification. While at low power, note the object's blue-green color. At 250x, the interior has the shape of a football and the inner 10" appears hollow except for a faint central star. A fainter shell some 40" across surrounds this oval disk. You don't even need a nebula filter to see this detail well. Backing off on the magnification and using a nebula filter on a large scope brings out a faint outer halo that spans more than 1'.

A long pan to the southwest brings **NGC 3109** into view. This nearby barred spiral galaxy lies near the edge of the Local Group. Although its luminosity places close to that of the Large Magellanic Cloud, it's only as big as the Small Cloud. NGC 3109 is an isolated galaxy, with its nearest neighbor, Sextans A, located some 1.3 million light-years away. Through a small telescope, NGC 3109 appears as a faint mist measuring 9' by 3'. Higher magnifications and increasing aperture reveal a surface punctuated with knots of



unresolved 18th-magnitude stars and clouds of ionized hydrogen.

The galaxy **NGC 3311** and its associated Hydra I Galaxy Cluster can be found 4° north-northeast of the 4th-magnitude star Alpha Antliae. NGC 3311 belongs to the class of cD galaxies, a type of supergiant elliptical usually located at the heart of galaxy clusters. These galaxies rank as the largest and most luminous in the universe. NGC 3311 spans nearly 200,000 light-years and possesses a rich system of globular clusters, rivaling that of M87 in Virgo.

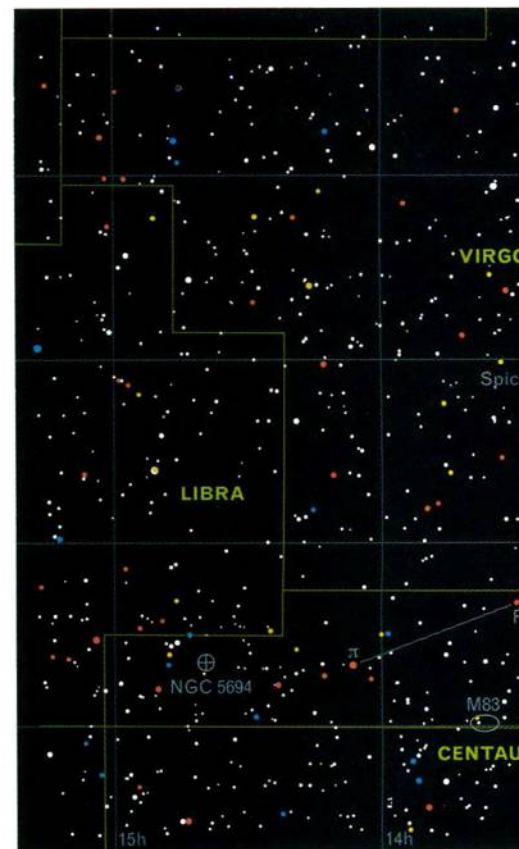
The Hydra I Galaxy Cluster seems similar to the Virgo Cluster in most respects but lies three times farther away. The telescopic field of the cluster teems with faint galaxies. In a field centered on two bright stars, a 10-inch telescope shows six galaxies in the central half degree. The brightest of these is NGC 3311, which appears as a circular haze 1' across with a brighter center. NGC 3309, another large elliptical that glows nearly as bright through the eyepiece, appears to be in contact with the western edge of NGC 3311. It looks circular as well, but a bit smaller than its neighbor. Only 5' to the southeast stands NGC 3312, an elongated glow measuring 2' long by 1' wide and oriented north-south. A 20-inch scope

at a dark site shows several dozen fainter galaxies spreading a degree in any direction from the cluster's center and a "lumpy" appearance of still fainter galaxies.

Five degrees south of Nu (ν) Hydrae lies one of the sky's most impressive carbon stars, **V Hydrae**. This star's brightness varies between 7th and 9th magnitude with a period of 1.5 years. Its most impressive characteristic, however, has to be its color. Even a conservative observer would describe its hue as rosy red. Although you might think it would be difficult to locate a 9th-magnitude star, its color boldly announces when you've swept it up.

Next head 7° southeast to 5th-magnitude Chi (χ) Hydrae, then another 2° east-northeast to **NGC 3585**. This spiral galaxy appears reasonably bright in a 10-inch scope, showing an oval halo 3' long and half as wide. Its core brightens steadily to a stellar nucleus that can be glimpsed with some difficulty. A 9th-magnitude star lies 9' east of NGC 3585.

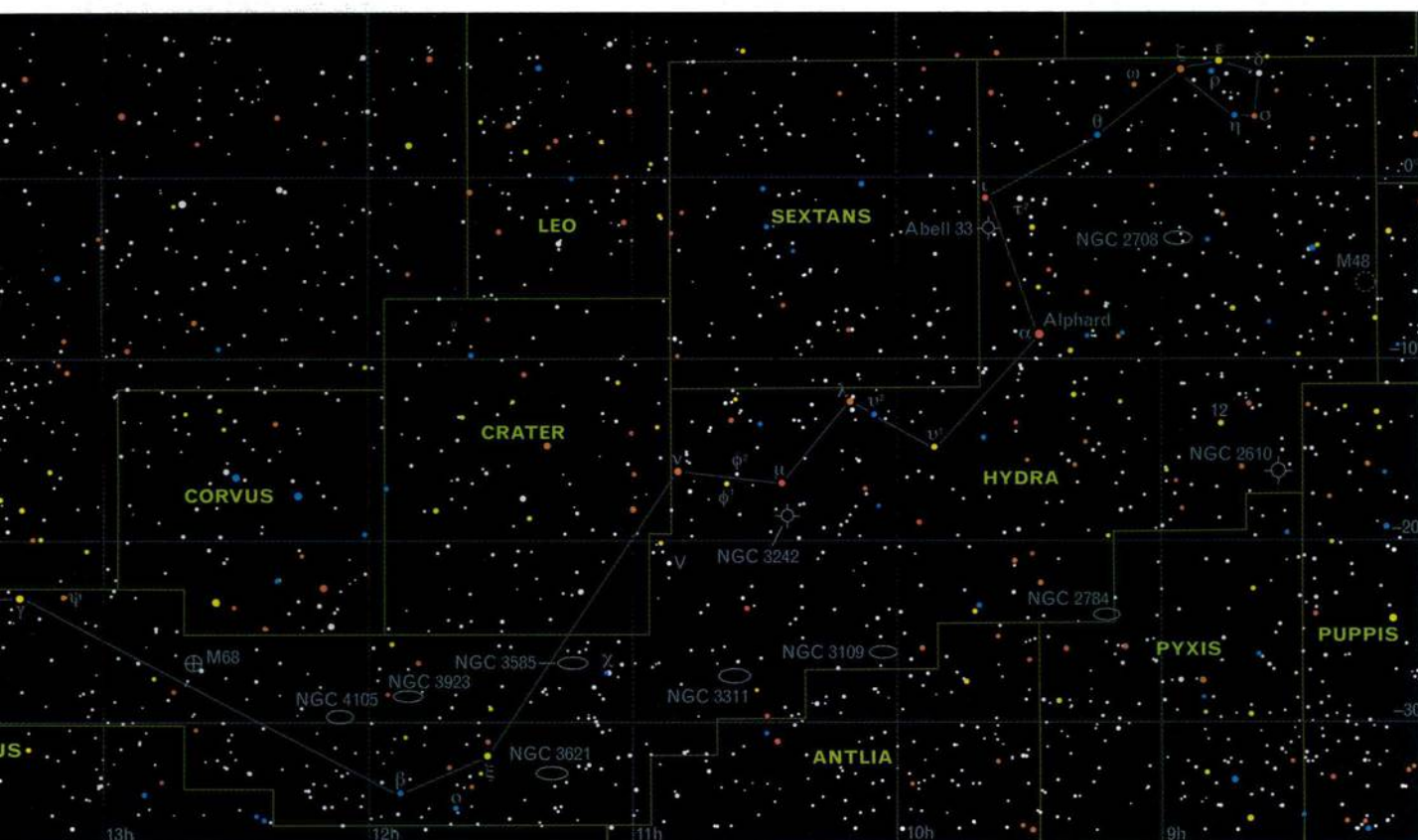
Sweep 6° to the south and your eyes will land on the isolated spiral galaxy **NGC 3621**. Hubble observations of Cepheid variable stars in this galaxy yield a distance of 20 million light-years. This relative proximity shows



itself in the eyepiece, as the galaxy extends nearly 6'. The oval glow drops off quickly to the background sky's brightness. At the center you'll find a brighter core measuring 15" across. Mottled structure across the galaxy's surface suggests spiral structure.

Forming an equilateral triangle with the stars Beta (β) and Xi (ξ) Hydrae lands the telescope on the elliptical galaxy **NGC 3923**. Astronomers estimate that it contains 4,300 globular clusters — the largest number known for any elliptical galaxy not belonging to a cluster. Advanced image processing techniques show an interesting shell structure, thought to be the remnants of a small galaxy merging with the large elliptical. NGC 3923 appears moderately bright in a 13-inch scope, with a sharp nucleus and a large oval halo surrounding it.

Now point the telescope 3.5° to the east-southeast and you'll come across **NGC 4105**, the brighter of a close pair of small galaxies. Their respectable surface brightnesses permit a good view at high magnification. NGC 4105 appears 2' across and just slightly out of round, with a bright center. The center of the overlapping galaxy NGC 4106 lies only 1' away. A near twin of NGC 4105, it appears just a bit smaller and



Deep-Sky Objects in Hydra

Object	R. A. (2000.0)	Dec.	Mag.	Size/Sep./Per.	Type	Notes
M48 (NGC 2548)	8h13.8m	-5°48'	5.8	54'	OC	
NGC 2610	8h33.4m	-16°09'	12.8	37"	PN	
Epsilon Hydrae	8h46.8m	6°25'	3.4/6.8	2.7"	Dbl	
NGC 2708	8h56.1m	-3°22'	12.0	2.6' by 1.5'	Gal	SAB pec
NGC 2784	9h12.3m	-24°10'	10.0	5.5' by 2.4'	Gal	S0
Abell 33	9h39.1m	-2°48'	12.4	268"	PN	
NGC 3109	10h03.1m	-26°09'	9.8	16.0' by 2.9'	Gal	SB(s)m
NGC 3242	10h24.8m	-18°38'	7.8	16"	PN	Ghost of Jupiter
NGC 3311	10h36.7m	-27°32'	10.9	4.0' by 3.6'	Gal	SA(r)0
V Hydrae	10h51.6m	-21°15'	6.6-9.0	531 days	Var	
NGC 3585	11h13.3m	-26°45'	9.7	6.9' by 4.2'	Gal	SAB(s)0
NGC 3621	11h18.3m	-32°49'	8.9	9.8' by 4.6'	Gal	SA(s)d
NGC 3923	11h51.0m	-28°48'	9.6	6.9' by 4.8'	Gal	E4
NGC 4105	12h06.7m	-29°46'	10.4	3.7' by 1.7'	Gal	E1
M68 (NGC 4590)	12h39.5m	-26°45'	7.7	12'	GC	
R Hydrae	13h29.7m	-23°17'	3-11	390 days	Var	
M83 (NGC 5236)	13h37.0m	-29°52'	7.6	15.5' by 13.0'	Gal	SAB(s)c
NGC 5694	14h39.6m	-26°32'	9.2	3.6'	GC	

Object: Designation in NGC or other catalog. **R. A. and Dec.:** Right ascension and declination in epoch 2000.0 coordinates. **Mag.:** Visual magnitude. **Size/Sep./Per.:** Size in arcminutes or arcseconds, separation in arcseconds, or period in days. **Notes:** Hubble type for galaxies.

The Water Snake

*"Well you're slim and you're weak,
You got the teeth of the Hydra upon you,
You're dirty sweet and you're my girl."*

Bang a Gong (Get It On)

Marc Bolan (1947–1977)

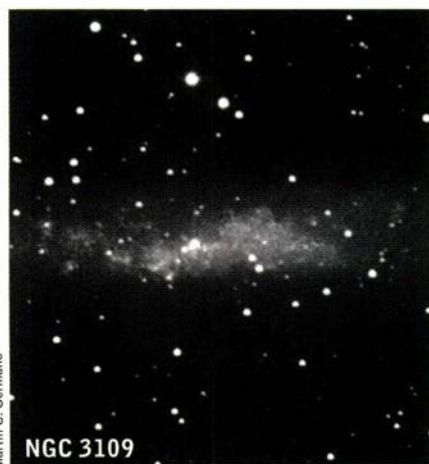
It seems appropriate that the largest constellation in the sky has one of the longest histories. The Hydra legend dates back at least to Sumerian times, some 4,500 years ago. Hydra was then associated with the goddess Tiamat, ruler of seawater and mother of all lesser gods. She had a bit of a mean streak, however, and plotted to kill her offspring. (The kids had murdered her husband, Apsu, the ruler of fresh water.) When the other gods heard Tiamat's plan, they sent the hero Marduk to defeat her. Marduk eventually dismembered Tiamat, and heaven and Earth were created from the body parts.

The Greeks had several legends entwined with Hydra, but the most enduring relates to the hero, Hercules. King Eurystheus of Argos imposed twelve labors on Hercules,



for which the hero would receive immortality. Second on the list was the slaying of Hydra, a feared monster who dwelled in the marshes of Lerna. Although we know Hydra as a water snake, the Lernean Hydra had the body of a huge dog and more heads than you'd want to count: nine according to some reports but as many as a hundred according to others. And the breath from any one of them was so vile it could kill.

Hercules lured the monster and — holding his breath with godlike endurance — hacked off the heads. Yet as one came off, two took its place. The stunned hero luckily learned that burning the neck stump prevented regeneration and, using the slash-and-burn technique, he triumphed over the hated Hydra. — *Richard Talcott*



Martin C. Germano

NGC 3109



John Chumack

NGC 3242

fainter. The two galaxies lie about 100 million light-years from Earth.

Another 8° to the east-northeast brings the fine globular cluster **M68** (NGC 4590) into view. Easily distinguished as a nonstellar haze in binoculars, an 8-inch scope reveals several dozen stars sprinkled across a broadly concentrated core. A 14-inch brings out twice as many stars in an area 8' across. Use high magnifications to see the cluster's member stars, which glow at 13th magnitude and fainter.

Moving down the tail of Hydra brings us to the bright Mira variable **R Hydrae**. It typically varies between 5th and 8th magnitudes with a period of

just more than a year, but occasionally grows as bright as 3rd magnitude. Seen through binoculars or a telescope, R Hydrae shows a distinct orange hue.

The globular cluster **NGC 5694** lurks near the eastern edge of Hydra. At a distance of about 115,000 light-years — a bit over three times farther than M68 — its stars appear more than two magnitudes fainter than those of its brighter cousin. (Glowing with the light of more than 200,000 suns, however, NGC 5694 would outshine M68 if they were at the same distance.) With its brightest stars coming in at 16th magnitude, it's hard to see more than a glowing ball that appears cometary in

any scope shy of 12 inches in aperture. Even a 20-inch does no more than show a clumpy appearance of unresolved stars. The cluster spans about 2' and has a well-concentrated center.

We end our tour right on Hydra's border with Centaurus with perhaps the most impressive barred spiral galaxy visible to northern observers. **M83** (NGC 5236) appears nearly face-on, so it reveals its spiral nature in scopes as small as 6 inches. Look for the bar emanating to the northeast and southwest from a bright, circular core. The spiral arm wrapping to the south from the bar's northeastern end shows up slightly better, but the other arm presents little challenge. Be sure to use sufficient magnification, and prevent any stray light from reaching the eyepiece. Large backyard telescopes reveal stellar associations and regions of ionized hydrogen peppering the spiral arms. The inside edges of the arms contain very thin dust lanes visible on the best nights. M83 belongs to the Centaurus A galaxy group, which lies about 10 million light-years away. **A**

Tom Polakis is an aerospace engineer living in Tempe, Arizona. His favorite astronomical pursuits are deep-sky observing and photography.



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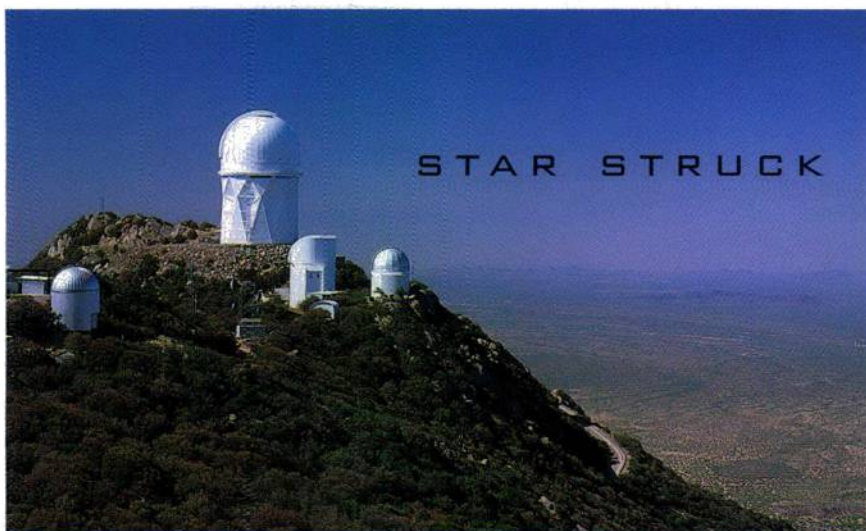


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"Imitated but never duplicated"

Beginner's sky

Diary of a neophyte astronomer. By Jerry Burstein

Whoever coined the phrase “patience is a virtue” must have been an astronomer. One of the most important things I’ve learned over the past few months has been to accept that accomplishments require time. My (often rambunctious) daughter, Amanda, and I usually expect to see everything we read about — such as Saturn’s rings, Jupiter’s Red Spot and the Orion Nebula — but that doesn’t always happen. Still, it’s been a fulfilling experience overall.

While we enjoy clear winter skies in our rural Southeastern Wisconsin location, the cold evenings often put a damper on our viewing efforts. Low temperatures alone could lead many to think astronomy is a tough hobby, yet the views offer new (and actually easy) opportunities to see something different, if not unexpected. Here are a few tips that have really helped us:

The Big Dipper is Your Friend

Consider *Astronomy*’s star chart and the Big Dipper among your best friends. Start by locating the Big Dipper — you’ve probably been able to identify that one since you were a kid. Use the two stars at the end of the Dipper’s bowl as key pointer stars. Follow them up to the North Star (Polaris), which is the last star on the end of the Little Dipper’s handle. Once you find Polaris, turn yourself and your star chart so that north on the guide matches north in the sky. By the way, if you can see at least three stars in the Little Dipper (there are seven total) you have a good shot at seeing lots of other things.

Pick Just a Few Items for Each Observing Adventure

Amanda and I have the best luck and most fun when we look for neat-sounding items like Ice Cream Cone, House, and Baseball Diamond. Recently, my daughter learned that her astrological sign is Aquarius and that mine is Leo, so we hunted for those constellations. Aquarius was dim and questionable, but using the pointer stars from the Big Dipper and looking south, we spotted Leo’s tail, as well as its “backward question mark” of a head. By choosing only two or three objects at a time, we

keep our adventures short and successful. This helps us maintain peak enthusiasm and interest levels.

Start with Binocular Observing

I’ve been fortunate (since I work for *Astronomy*) to have use of both a telescope and binoculars in our adventures. To lessen our frustrations with the scope and its various lenses, we’re practicing with it on terrestrial targets during the day — which has helped us get used to the upside-down visual thing. As the scope sits idly by, the binoculars are put to good use. January treated us to great views of Jupiter and Saturn, but it also made me realize the importance of using a binocular mount for increased steadiness and reduced arm fatigue.

Share Your Experiences

Sharing our newfound knowledge with family and friends is key to staying interested in astronomy. And as the weather gets warmer I’m psyched about

attending star parties. I encourage you to do the same.

Astronomy’s website (www.astronomy.com) can help you discover astronomy clubs in your area (there are more than 400 in North America alone). I’m also hoping to visit a nearby observatory soon with Amanda.

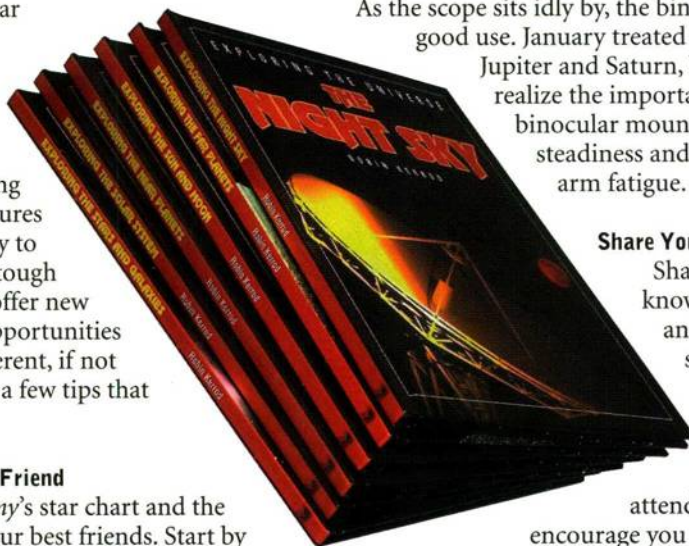
I’ve received some great e-mails from readers. Please send your thoughts and experiences to jerry@astronomy.com. And don’t forget to relax, enjoy, and have fun observing.

Exploring the Universe Series

Raintree Steck-Vaughn Publishers, Austin, Texas, 2001; six-book hardcover set; ISBN 0-7398-2821-5; \$113.88.

Author Robin Kerrod covers the following subjects in this overview of astronomy: *The Night Sky*, *The Solar System*, *The Sun and Moon*, *The Near Planets*, *The Far Planets*, and *The Stars and Galaxies*.

Aimed at the junior-high level, this series brings the enormity and wonder of the universe to readers in easily understandable terms. Each richly illustrated book concentrates on a specific theme and discusses recent astronomical discoveries. Titles are also available separately for \$18.98 per book.



Target^{Leo}

Mu Leonis

Leo's muzzle is known
as Ras Elased.

Adhafera

Eta Leonis

Double-star Al Geiba,
together with Adhafera,
marks Leo's mane.

Regulus is the brightest
star in Leo.

Zosma

Chort
Think of Chort and Zosma
as Leo's hind legs.

Denebola represents
the lion's tail.

Follow the Big Dipper pointer stars Dubhe and Merak (See "Double Dipping," page 79) south to locate Leo the Lion — one of the few constellations that resembles its namesake. A spring constellation, Leo lies in wait along the horizon in April. Its brightest star, Regulus, rides the ecliptic. Look for the backward question mark that forms the lion's head, mane, and front paws — while Leo's body and tail stretch to the left.

Beginner's

helpful tips

More tips for first-time telescope buyers.

Many experienced observers advise beginners against an immediate purchase of a telescope. Develop a familiarity with the night sky through naked-eye and binocular observing, they say. But if you can't resist the urge, at least remember these tips:

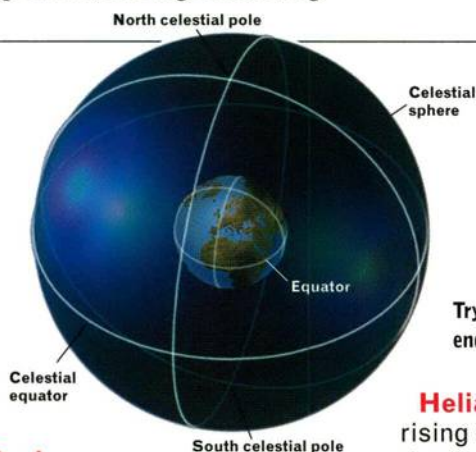
Determine your interest: Planetary and lunar observers should select a scope that delivers the sharpest images and highest contrast. Apochromatic refractors reduce the effects of chromatic aberrations, or false-color images. Aim for a telescope with a focal ratio between f/8 and f/15.

If galaxies, star clusters, and nebulae excite you, check out the largest-sized aperture reflector telescope that you can afford. The bigger the aperture, the higher the light-gathering potential.

Location, location, location: Where will you do most of your observing? Astronomers who live in rural areas can probably walk out their back door, wait for the telescope to acclimate to the ambient temperature, and begin observing.

City folks, on the other hand, need to consider logistics such as weight and shape (the telescope's — not the observer's). Think about hauling that scope in and out of your vehicle without entangling it in seat belts or all that stuff in your trunk. Could you trek through a dark park with it? And even if the scope is fairly light-weight, how do you feel about climbing to the best vantage point with such an irregular load under darkness?

Assembly required: Stay alert to how the scope fits together. If the tripod has a zillion parts with screws and washers that are easy to drop but hard to find, you will only want to assemble it once in your lifetime. (Believe it.) If the completed telescope is compact enough to carry around and store in its assembled state, count your blessings. But take heart — there are plenty of beginner scopes out there that practically snap together in five minutes or less. When in doubt, ask if you can disassemble and reassemble the model you are considering buying.



Glossary

Try to imagine a giant celestial sphere encircling Earth. *Astronomy: Rick Johnson*

Albedo: the reflective power of objects — such as a planet, the moon, or an asteroid.

Aperture: the diameter of a telescope's primary lens or mirror; the larger the aperture, the greater the telescope's light-gathering power.

Celestial sphere: the apparent sphere of the night sky; an imaginary sphere of immense radius centered on Earth that's used to plot the coordinates of objects in the sky.

Heliacal rising: the rising of an object, such as a star or planet, briefly in the eastern sky before dawn, prior to being washed out by the glare of the sun.

Inferior planet: a planet that orbits the sun inside Earth's orbit; includes Mercury and Venus.

Pulsar: a rapidly spinning neutron star that emits electromagnetic radiation in regular, periodic pulses. When pulsars were first detected in 1967, they were referred to as "little green men" (LGM).

Quasar: the extremely high-energy core of a young galaxy that emits large amounts of radiation. Quasar is short for quasi-stellar radio object, also known as a QSO.

Superior planet: a planet that orbits farther from the sun than Earth; includes Mars, Jupiter, Saturn, Uranus, Neptune, and Pluto.

Syzygy: describes an alignment of the sun, Earth, and either the moon or another planet; this configuration can also be called conjunction or opposition.

Double dipping

Polaris, the North Star, remains relatively stationary near the North Celestial Pole throughout the year.

Eta Ursae Minoris

Zeta Ursae Minoris

Pherkad is a blue giant that appears to have a distant partner in 11 Ursae Minoris.

You'll need a telescope to see Kochab's reddish tinge.

Locate Polaris by tracing a line northward from Merak and Dubhe.

Dubhe

Merak

Megrez

Naked-eye double star Mizar and Alcor shines in the center of the Big Dipper's handle.

Alioth is the brightest star in the Big Dipper.

Phecda

Alkaid

Exploring the Bowl of the Big Dipper

by Robert Garfinkle

The first asterism you learned to identify was probably the Big Dipper in the constellation Ursa Major (UMa). The four stars at the corners of the Dipper are easy to locate with the naked eye, but our main targets on this star-hop are interesting galaxies, double stars, and an easy-to-find planetary nebula located near these bright stars. This star-hop is favorably positioned for April, as the Big Dipper rides high in the

Northern Hemisphere evening sky, but can be done during any time of the year as the Dipper is circumpolar for Northern Hemisphere viewers.

When hunting for galaxies, always try to do so from a dark observing site on a moonless night, and use a low-power eyepiece that yields 30x or 50x. Once you find a galaxy, then switch to higher magnifications to study its details. To keep from getting lost on this hop, con-

sult a good star atlas like Wil Tirion's *Sky Atlas 2000.0*.

Let's start a clockwise hop around the bowl of the Dipper at **Megrez** (Delta [δ] Ursae Majoris), which is the star at the intersection of the handle and the bowl. The name for this magnitude 3.3, blue-white star comes from the Arabic *Al Maghrez*, an obscure word which means "root of the tail."

Megrez is about one billion years old, shines with a luminosity 90

My Favorite Objects/Jack Newton, Osoyoos, British Columbia

I've been an amateur astronomer since my early junior high school days. Having been given a 2-inch refractor by my parents, I immediately set out investigating craters on the moon and even "independently discovered" Saturn. Many of the objects I enjoyed then remain favorites now. I never get tired of sharing the night skies with guests who come to stay with Alice and me at our astronomy-themed bed-and-breakfasts in Osoyoos, Canada, or in Florida. (For more on them, see www.jacknewton.com.)

The Hercules Cluster

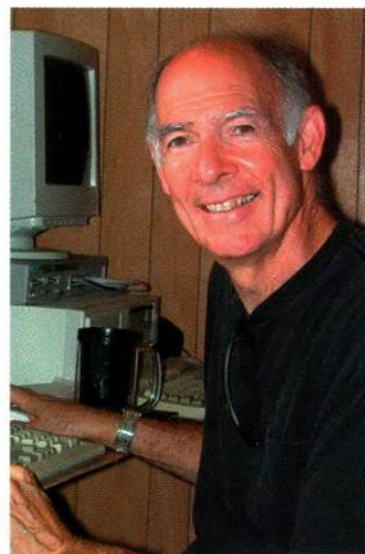
The great cluster in Hercules, M13, is one of my favorite summertime objects. Through my 16-inch SCT at 200x, the dazzling cluster appears like thousands of blue-white diamonds cast onto jet-black velvet in a three-dimensional matrix. I still feel my heart rate quicken when looking at it and I feel enormous pleasure in showing this object to our guests. This cluster is one of the top treats in the sky and should be viewed by every beginning skywatcher.

The Whirlpool Galaxy

This object, M51 in Canes Venatici, is a most beautiful galaxy. Rivaling the Andromeda Galaxy for my attention, M51 was the first galaxy in which I saw spiral structure. I once took a deep exposure with my 7-inch apochromat and discovered that two long, faint spiral arms emanate from its companion, NGC 5195.

Elliptical Galaxy M87

My springtime favorite is M87 — not so much for its pleasure to the eye as for what a CCD camera can glean from it. When I took my first 30-second exposure of this giant galaxy I could hardly believe my eyes, as the shot clearly showed the dramatic jet blasting away from the galaxy's nucleus. Here was a record of material shot away from a supermassive black hole that has purportedly swallowed on the order of 40 billion solar masses. I often get requests from guests to show them a black hole and explain that, while I can't do that, I can show an example of the effect of a black hole on a galaxy.



Jack Newton

The Sun

I'm relatively new to H-α solar photography, but it took little time for the sun to become my favorite star. I use a Coronado Instruments' SolarMax 90mm H-α filter and a 7-inch apochromatic refractor. The photosphere comes alive with micro loops in a magnetic dance. White-hot fissures crack the surface and prominences explode in every shape and size. It's a "religious experience."



Barred spiral NGC 3359 offers the challenge of spotting fine details. John C. Vickers



Edge-on spiral M108 lies near the low-surface-brightness Owl Nebula. Jack Newton



Galaxies NGC 3718 and NGC 3729 provide a striking contrast. James R. Foster



Irregular galaxy M82 is undergoing a chaotic starburst. Tim Hunter and James McGaha



The Owl Nebula, M97, is one of the most challenging Messier objects. Jack Newton



Bright barred spiral M109 shows structure even in small scopes. Jack Newton

times brighter than the sun, and has a surface temperature of 9 to 10 million K. The star lies at a distance of 65.2 light-years. Including Megrez, the stars at the corners of the Dipper constitute a portion of an open cluster centered about 70 light-years away, and are dubbed the Ursa Major Moving Group.

Find Megrez and place it in the center of your finder scope. About $1\frac{1}{2}^\circ$ northeast of the star you'll find a magnitude 5.5 bright orange giant star dubbed 70 Ursae Majoris amid several fainter stars. If you draw an imaginary line from Megrez through 70 UMa and extend the line to the faint white star near 70 UMa, you'll be looking at the double star Winnecke 4, which is more commonly known as M40.

This object was identified as number 40 in the catalog of comets compiled in the late 18th century by the French comet hunter Charles Messier. The normally keen-eyed observer somehow convinced himself that this double star was nebulous, and so it's thought of as an error in the catalog. This double star and its companion each glow at about magnitude 9 and were first measured by German astronomer Friedrich Winnecke in 1863.

Use M40's two stars to point you toward the SBB-type barred spiral galaxy NGC 4290. This galaxy appears elongated and is faint at

magnitude 12.4. It lies some 140 million light-years away.

Continuing on, you'll find the ruddy magnitude 1.8 star Dubhe (Alpha [α] Ursae Majoris). This fine star is a double and you'll find its magnitude 4.8 bluish companion just south of it. Of the four bowl stars, Dubhe is the brightest — about 145 times brighter than the sun — and is also the most distant, at 105 light-years.

Let's leave the Dipper for a short side-trip to four galaxies. Place Dubhe near the southeastern edge of your finder scope and the magnitude 10.5 S(B)c-type barred spiral NGC 3359 will be near the center of your low-power field of view. As a challenge, use a high-power eyepiece to observe the north-south bar near the galaxy's core.

As you did with Dubhe, place NGC 3359 near the southeastern edge of your finder and you'll have the magnitude 12.9 irregular galaxy NGC 3259 near the center of a low-power field. This galaxy is oval shaped and much smaller than NGC 3359. It's a little difficult to see, but challenge yourself by using averted vision to spot it.

Continuing in the same direction, one finder hop away, are the bright galaxies M81 (NGC 3031) and M82 (NGC 3034). In a low-power eyepiece you can probably just fit both galaxies in the field.

The magnitude 6.8, oval-shaped M81 was first seen by the German astronomer Johann Elert Bode on the last night of 1774. This galaxy appears large and bright compared with its narrower companion M82. Both are about 16 million light-years away.

M82 is a distorted galaxy, having undergone a massive series of explosions and starbursts in its core. A hot, polarized stream of gas is moving away from the galaxy's core. Both galaxies are marvelous in small scopes; see if you can detect M81's spiral arms after studying its core carefully.

Now head back to Dubhe. From this star, move south to Merak (Beta [β] Ursae Majoris), the magnitude 2.4, blue-white star at the southwestern corner of the bowl. Merak is a subgiant that shines with the light of 33 suns. Place Merak near the northwestern edge of your finder scope view. Within this field, you'll see the barred spiral M108 (NGC 3556) and the faint planetary nebula M97 (NGC 3587), dubbed the Owl Nebula.

We see M108 almost edge-on and so it appears as a faint streak oriented east-west. Its apparent magnitude is 10.2. The celebrated Pierre Méchain, a French astronomer and collaborator of Messier's, discovered the galaxy.

Just $48'$ southeast of M108 floats



Spiral galaxy M81, one of the brightest in the sky, offers spiral arms to observers viewing with 6-inch or larger scopes. Jason Ware

the diffuse glow of the Owl Nebula. You'll see it northeast of and close to a 6th-magnitude star. Look for a 10th-magnitude glow about the size of Jupiter's disk that appears as a fuzzy "star." Unless you're observing on a very dark night and with a 6-inch or larger scope, you may not see the two dark patches — "eyes" — that gave rise to the object's sobriquet.

A challenging, 14th-magnitude central star lies within an expanding shell of hot gas, and you may see a small triangle of glistening foreground stars near the apparent center of the shell. The brightest of these stars is a white dwarf. Méchain discovered this object on the night of February 6, 1781.

Our next targets are galaxies. Located midway between Merak and Phecda (Gamma [γ] Ursae Majoris), these galaxies can be glimpsed in 6-inch scopes and show some detail in larger instruments. To find them, imagine a line drawn between Merak and Phecda and center your finder scope between the two stars. You'll see a string of four 6th-magnitude stars forming a northeast-southwest line. You may see a little group of very faint galaxies near the second southwestern star in this line.

Just east of the star lies NGC 3738, an irregularly-shaped galaxy glowing at magnitude 12. Southeast of NGC 3738 is the spiral NGC 3756. This object appears elongated and thin. A pair of distorted spiral galaxies, NGC 3718 and NGC 3729, floats about one star-hop south of the last star in the line of 6th-magnitude stars. NGC 3729 appears considerably smaller and brighter than NGC 3718. Both are about 55 million light-years away. At magnitude 11.9, NGC 3718 has a bright core. However, its partner shows almost no core.

Phecda is a hot, blue-white star with a luminosity some 75 times greater than that of the sun. This star lies 75 light-years away. Center your finder on Phecda and move southeast of the star to find the barred spiral galaxy M109 (NGC 3992). This galaxy has what appears to be a very bright core, but it's actually light from a star in our galaxy that is superimposed on the galaxy's face.

Challenging Comets/ Apr. 2002

In any month, usually several comets glow brightly enough to become visible to those with large telescopes. Here are coordinates and magnitudes:

7P/Pons-Winnecke

Apr. 1 18h34.8m, 0°46', 11.8
Apr. 11 19h09.9m, -0°46', 11.5
Apr. 21 19h46.5m, -2°44', 11.1
May 1 20h24.2m, -5°11', 10.8

C/2000 SV74 (LINEAR)

Apr. 1 0h07.8m, 63°53', 14.0
Apr. 11 0h22.9m, 66°25', 14.0
Apr. 21 0h40.6m, 69°10', 14.0
May 1 1h01.9m, 72°08', 14.0

C/2001 N2 (LINEAR)

Apr. 1 20h34.1m, 16°16', 15.0
Apr. 11 20h31.0m, 17°13', 14.8
Apr. 21 20h25.3m, 18°15', 14.6
May 1 20h16.2m, 19°21', 14.3

C/2001 W2 (BATTERS)

Apr. 1 21h44.3m, -52°47', 15.1
Apr. 11 22h08.1m, -59°16', 15.3
Apr. 21 22h39.5m, -66°11', 15.5
May 1 21h42.1m, -52°08', 15.0

29P/Schwassmann-Wachmann 1

Apr. 1 20h52.3m, -19°21', 15.7
Apr. 11 20h57.7m, -18°55', 15.6
Apr. 21 21h02.3m, -18°32', 15.5
May 1 21h05.9m, -18°12', 15.5

19P/Borrelly

Apr. 1 11h46.3m, 51°23', 15.5
Apr. 11 11h37.1m, 49°28', 16.0
Apr. 21 11h31.7m, 47°10', 16.4
May 1 11h29.8m, 44°39', 16.9

C/1999 Y1 (LINEAR)

Apr. 1 22h17.7m, -54°04', 15.7
Apr. 11 22h22.2m, -55°32', 15.7
Apr. 21 22h25.4m, -57°17', 15.7
May 1 22h27.0m, -59°17', 15.8

Telescope Tales

Takin' it to the Streets

Aperture, location, and convenience. I had it all, and then it was gone. It was a 16-inch classic Newtonian on an equatorial pier, adjacent to my farm home in rural Kansas. Then came the move to town, a suburban neighborhood, streetlights, cars, tall trees, and neighbors. A 700-pound scope didn't get used much when I had to roll it out onto the driveway just to see a sliver of hazy sky.

The solution came when I spotted a used ambulance for sale. In December 2000 I began converting the vehicle and first light occurred in August 2001. I had a shop cut a 6-foot hole in the roof, then weld a base flange that would support a dome assembly I purchased. I mounted a pier to the chassis of the vehicle and had box-beams welded to the vehicle so it can be raised when on location. A 12-volt battery powers the scope's electronics. A new 11-inch SCT now rests inside the ambulance, ready to show me the darkest skies I can drive to on any given night. — *Jim Sheets, McPherson, Kansas*

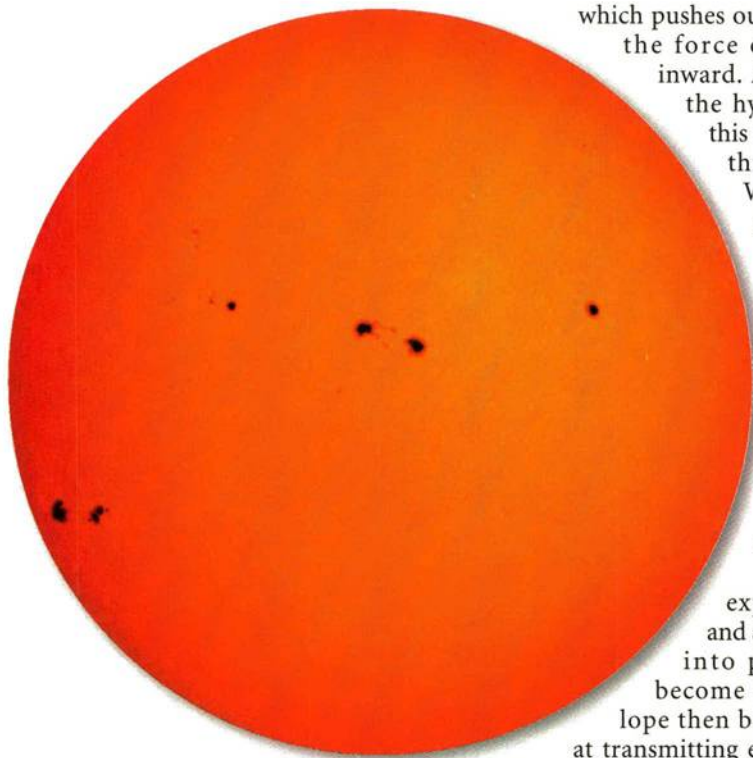
After taking this simple star-hop tour, slowly sweep through the area within the bowl. You may discover two dozen additional galaxies, many of which show details in small scopes. These objects constitute a small portion of the Virgo Cluster of galaxies. To get an idea of how massive this collection is, scan from

Ursa Major toward Virgo and Coma Berenices. This large swath of sky is loaded with galaxies, the majority belonging to the Virgo Cluster. ■

Robert Garfinkle is the author of Star-Hopping: Your Visa to Viewing the Universe (1994).

ask Astro

Red Giants, Planets in Transit, White-light Filters



The sun may be stable now, but in five billion years it will become a red giant. NOAO/AURA/NSF

What mechanism causes a main sequence star like the sun to expand when its hydrogen has been consumed? — Gary Engebretson, San Diego, California

All stars spend the vast majority of their lives on the so-called main sequence, fusing hydrogen into helium and releasing energy in the process. As this hydrogen burning progresses, the star develops a core containing the helium ashes and an envelope composed of the hydrogen-rich material from which the star was born.

For a star to remain stable, the pressure exerted by gas within the star,

which pushes outward, must balance the force of gravity pulling inward. As the star exhausts the hydrogen in its core, this delicate balance gets thrown out of whack.

When the star's source of energy dries up, the gas pressure drops and gravity forces the core to shrink. Under these conditions, the core and the region immediately surrounding it grow hotter and the star's envelope expands in response.

As the envelope expands it also cools, and a second factor comes into play: cooler gases become opaque. The envelope then becomes less efficient at transmitting energy from the core region and it absorbs extra power. This "trapped energy" drives a further expansion of the envelope and thus of the star's visible surface. A third factor pushing the expansion emerges when the outer surface of the core grows hot enough to initiate hydrogen fusion, which generates even more energy.

What finally reins in this cycle is a switch in the way energy gets transported outward from the relatively inefficient means of radiation to the much more effective method of convective gas motions. Once convection becomes established throughout much of the envelope, the star's surface temperature stays low and roughly constant and the star's size increases only in response to greater energy generation in or near the core. The star has then become a typical red giant. — Jay Gallagher, University of Wisconsin

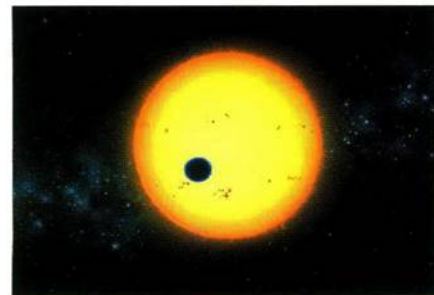
Once astronomers detect an extrasolar planet transiting its parent star, how do they determine its size, mass, and density? — Jean Waldbieser, Lynn, Massachusetts

The transit method cannot, by itself, determine the mass of a planet. Astronomers found the minimum mass of the first transit planet, HD 209458b, by the radial velocity method — observing how much the planet caused its parent star to "wobble," which showed up as a shift in the lines of the star's spectrum. Yet this method measures only the motion toward and away from us. The complete motion may include a component at right angles to our line of sight, so the observed motion represents only a minimum estimate of the entire motion. That's why we get only a minimum mass for the planet.

When HD 209458b transited its parent star, however, the giant planet had to be moving directly across the star's face. That meant that the plane of the planet's orbit had to lie essentially edge-on to our line of sight, and the motion toward and away from us must have been the entire motion produced by the planet. So the minimum mass deduced from the radial velocity method had to be the total mass.

By measuring how much the star's light dimmed during the transit — and thus what fraction of the star's area the planet blocked — the observations provided the planet's size. From the area of the planet we computed its volume, and dividing mass by volume yielded density. This provided the first test of models describing giant extrasolar planets, and the models — which predicted "puffed up" planets 40 percent larger than Jupiter — turned out to be almost exactly correct. — Lawrence R. Doyle, SETI Institute

When a planet transits its parent star, astronomers can calculate its size and density.



Lynette Cook

I recently purchased a white light filter and was wondering how it can filter out long wavelengths (infrared) and short wavelengths (ultraviolet) at the same time but allow the in-between wavelengths (white light) through? — Richard Nelson, Crystal Lake, Illinois

Filters work in several different ways depending on their purpose and design. An optical filter, such as your white light one, typically blocks out light from other wavelengths by either interference or absorption. Earth's atmosphere absorbs most of the non-optical light, however, so a filter doesn't need to remove far-infrared and most ultraviolet light. Besides the visual wavelengths and a bit of the infrared and ultraviolet, the atmosphere lets through only radio radiation. That's why far-infrared, ultraviolet, x-ray, and gamma-ray astronomy must be done from space. And remember that your eye can't see the ultraviolet or infrared light that does pass through the atmosphere. Some filters remove those wavelengths anyway, however, because CCDs can record them. (Solar filters also block infrared and ultraviolet radiation because of the sun's brilliance.)

To answer your question, all visual wavelengths combine to form white light. So the filter you have transmits nearly all visual wavelengths and blocks only a small portion of the light humans can see. Other filters used by professional and amateur astronomers let through only certain wavelengths, such as red or blue colors.

Some molecules absorb all wavelengths except particular ones, and filters can be created out of these substances. They are called absorption filters. Colored glass is an example of this type of filter, although liquids and gases can be used for the same purpose. Interference techniques offer another method for filtering out light. When light goes through this type of filter, it must pass through two semi-reflective surfaces separated by a transparent spacer. By carefully choosing the size of the spacer, the filter transmits only certain wavelengths. All other wavelengths are reflected by the two surfaces and cancel each other out

by destructive interference, allowing only the desired wavelength to pass. Many common filters are of the absorption variety, while narrow-band filters such as H- α filters are of the interference type. — *Chris Conselice, Space Telescope Science Institute*

Where does the name for our planet "Earth" come from? What does the word mean? — John Merchant, Charleston, South Carolina

The realization that Earth is a planet dates only from the time of Copernicus, who published his heliocentric model of the universe in 1543, but people have known since prehistoric times that Earth is a large solid object. The English word "earth" has ancient roots. A thousand years ago, the word "eorthe" in Old English already meant "earth" (the object), "ground" (the surface of Earth), and "dirt" (what the Earth is made of). Until the 1800s, earth also meant "land" in the sailor's sense, the opposite of water.

Ultimately, Earth comes from "er" in Indo-European, a prehistoric language



Earth's name comes down to us from ancient English.

F. Hasler, et al. (NASA Goddard Lab for Atmospheres/NOAA)

spoken about 2500 B.C. that has been reconstructed from its descendants. Related words have been found in Ancient Greek and possibly Celtic.

The Latin word "terra," unrelated to earth, had the same set of meanings throughout its history: "earth" (the object), "ground" (the surface), "dirt" (the substance), and "land" (in contrast to water). Unlike earth, terra also meant "land" in the political or geographic sense, such as the land of Canaan or the land ruled by a king. — *Michael Covington, author of Astrophotography for the Amateur, studied historical linguistics at Yale University and now does research on computer processing of human languages at the University of Georgia.* **A**

CONTACT INFO

Send your questions via e-mail to: askastro@astronomy.com; or write to: Ask Astro, P.O. Box 1612, Waukesha, WI 53187. Please tell us your full name and where you live.

A PRODUCTS

Fisher Space Pens Perform in Extreme Conditions

Gravity works. That's the principle driving most ball-point pens. When held upside-down, at odd angles, or in zero gravity, however, regular pens often fail. Many pens also stop working in extreme heat or cold. So in 1967, with the launch of Apollo 7, NASA selected Fisher Space Pens as the writing instrument of choice for astronauts. These pens have flown on every U.S. space mission since and have been used by Russian cosmonauts as well.

Several factors make Fisher Space Pens stand out. An innovative design couples a pressurized ink delivery system with a gel-like (thixotropic) ink. This special ink changes consistency on contact with the tungsten-carbide ball, allowing these pens to write evenly no matter the writer's position. And any Fisher Space Pen can make a continuous line stretching roughly 30,000 miles before going dry.

They will also write under water and over grease and oil, if necessary.

Fisher Space Pens offers quite a variety of pens for different users. At least ten special designs, sizes, and colors are available. A compact telescoping model reaches barely five inches when fully extended and collapses into a handy size for pocket or purse. An underwater model rated for depths of 120 feet below sea water (~five atmospheres of pressure) is made of plastic and rubber.

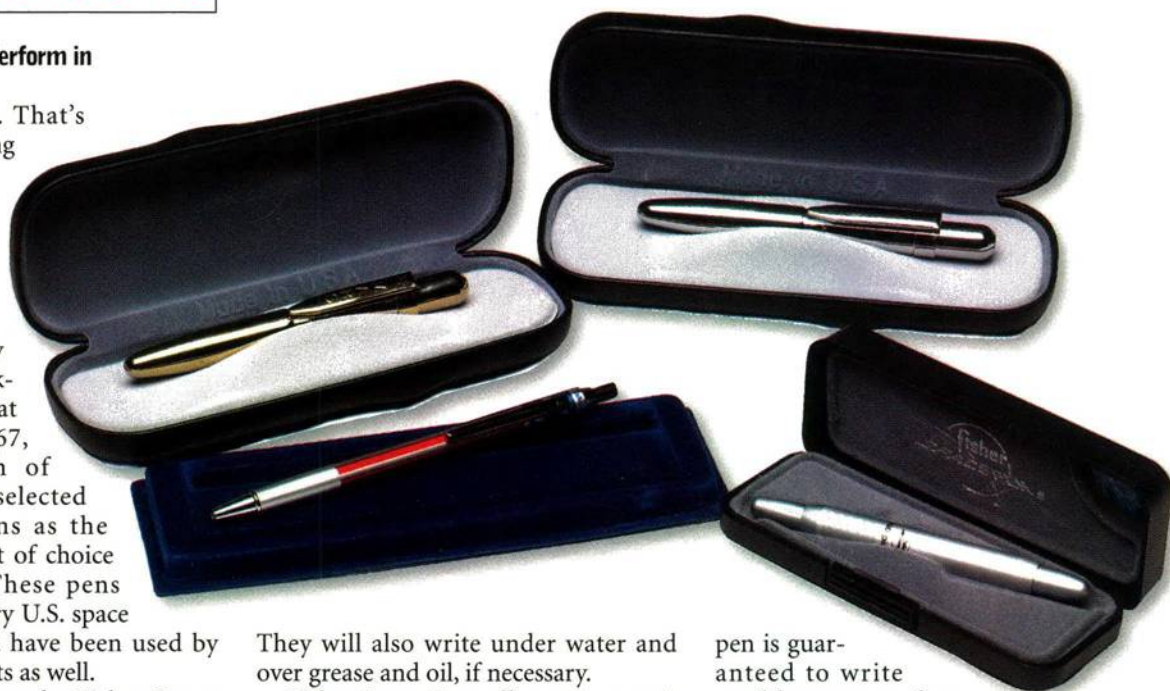
The Millennium pen comes with a lifetime guarantee; if for any reason the pen stops working, Fisher Space Pens will replace it free of charge.

Likewise, the Mars

pen is guaranteed to write until humans set foot on the Red Planet.

These pens are expected to write for decades rather than a year or two. Other designs include a conventional-sized, patriotic flag pen with stars and stripes, a gold Mars pen, and a bullet pen. Insignia pens featuring Coast Guard, Army, Navy, Marine and Air Force logos make great presents for veterans and military personnel.

Prices range from \$11 to \$200. Fisher Space Pen Company, 711 Yucca Street, Boulder City, NV 89005-1905; (702) 293-3011; fax: (702) 293-6616; website, www.spacepen.com.

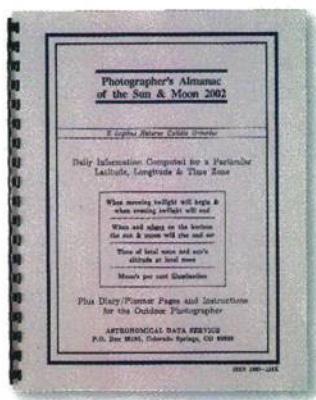


Compact Binoculars Easy to Carry

Binoculars are the perfect traveling companion for amateur astronomers. This nine-ounce pair by Scientifics measures 4.3" by 4.0" by 2.0" and is so convenient to use that you'll always want to keep them handy.

Manufactured by Carson Optical, the 26mm multicoated objective lenses provide a broad (5.2°) field of view and 10x magnification. Features include an easy-adjust center focus and a carrying case with a belt loop. Cost for model #30822-79 (pictured) is \$69.95.

For information, contact: Scientifics, Dept. A021-C999, 60 Pearce Avenue, Tonawanda, NY 14150-6711; (716) 874-9091; (800) 728-6999; fax: (800) 728-3299; e-mail, cons_order@edsci.com; website, www.scientificsonline.com.



Photographer's Almanac Plots Sun and Moon

Astronomical Data Service offers the *Photographer's Almanac of the Sun & Moon 2002*. Each booklet is customized according to the observer's longitude, latitude, and time zone. Helpful information assists photographic or observing sessions. Tables include times and dates for lunar phases, as well as for sunrise and sunset. Six pages of instructions offer tips on compass use and landscape photography. Suggestions for further reading and references are also included.

Each booklet costs \$20, postpaid. Price includes a complimentary copy of SKYWATCHER software for Windows-based PCs.

Astronomical Data Service, P.O. Box 26180, Colorado Springs, CO 80936; (719) 597-4068; e-mail, astroger@worldnet.att.net; website, http://home.att.net/~sky_watcher/.

Life Everywhere: The Maverick Science of Astrobiology

David Darling, 206 pages, Basic Books, New York, 2001; ISBN 0-465-01563-8; hardcover, \$26.

David Darling presents a concise, well-written, and entertaining book that builds a convincing case for the inevitability of life arising from inorganic matter when the proper conditions are met. While this thesis is sure to raise the eyebrows, if not the hackles, of many non-biologists, *Life Everywhere* is a comprehensive examination of the state of astrobiology. Using a straightforward writing style,

Darling walks us through the research being conducted in diverse scientific disciplines in order to eventually answer the question, "Does life exist elsewhere in the universe?"

One of the first steps in mounting a search for extraterrestrial life is to define what one is looking for. Rather than debating what life is — a subject best left to the theologians — most astrobiologists focus on how life behaves. Darling begins with "The Intimate Mystery," an examination of what the most important criteria are for defining life, and discusses how life may have evolved on Earth. Our planet serves as the only proven example of life in the universe at present, making the study of evolution fundamental to the science of astrobiology.

A lively discussion follows on the merits of the two competing schools of thought on the origin of life on our planet. The "surface, sunlight guys" believe that life began in a warm sunlit pond, and the "deep, dark guys" believe it all started in a deep hydrothermal vent. Darling presents each side in an organized fashion, without committing himself clearly to either camp.

He then takes us on a tour of the formation of the galaxy and our solar system. We are shown how current research indicates that organic molecules may form within the icy coating of silicate grains in deep interstellar space, facilitated by ultraviolet-light-powered photochemical reactions.

If this is indeed the case, it implies that organic material was present during the formation of our own solar system.

Darling emphasizes that, in order to begin the life "cascade," three critical ingredients — concentrated organic chemicals, a suitable energy source, and liquid water — must exist simultaneously. And in a discussion of the conditions required for a planet-wide ecology to form and sustain itself, he stresses that plate tectonics looms large:

A Caltech planetologist theorizes that water carried into the mantle of a planet lubricates the sliding of the crustal plates; without this water, plate tectonics would grind to a halt. Because Earth is the only place in the solar system that has both liquid water and plate tectonics, a planet-wide ecology is unlikely elsewhere in our immediate celestial neighborhood.

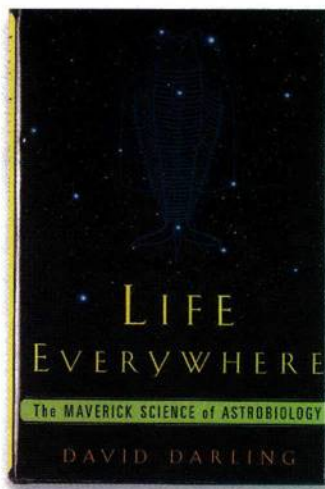
This may surprise most readers, yet without plate tectonics there would be no carbon dioxide recycling loop. Carbon dioxide would either build up massively in the atmosphere (as on Venus) or become mineralized and mostly sequestered beneath the ground (as on Mars).

In later chapters, Darling details the most promising places in our solar system that may shelter and support life, and what type of technology would be required to find it.

While for the most part the book is a well-balanced and thoughtful account, a chapter entitled "Rare Earths and Hidden Agendas" shifts from scientific objectivity to what some might consider a personal attack. Darling contends that one astrobiologist in particular distorts his research findings in order to prove what he already believes, all the while hiding an affiliation with the creationist school of thought — hence the "hidden agenda" of the chapter title.

The author includes personal correspondence to support this claim, which is somewhat jarring in that it is out of character with the much more objective and scientific tone of the rest of the book.

This quibble aside, *Life Everywhere* is a must-have for anyone interested in biology, evolution, or the new and startling discoveries we may expect to find in the coming decades — both close to home and throughout the universe. — *Hydrogeologist John E. Schindler has researched watershed carbon cycling throughout North America as well as in Antarctica.*





Astrobiology

Monica Grady, 96 pages, Smithsonian Institution Press, Washington, D.C.; 2001; ISBN 1-56098-849-5; softcover, \$14.95.

Recent pronouncements of possible hidden oceans on jovian moons and hints of microbial life in martian rocks have increased research in astrobiology. Beginning with the origin and formation of the universe, *Astrobiology* explores the leading scientific ideas surrounding the potential for life outside our planet. With Earth as a starting point, key factors such as habitats and chemical building blocks necessary for biological development are introduced with dramatic photos and clear text.

Monica Grady, lead meteorite scientist of The Natural History Museum in London, discusses the possibility that worlds within the solar system — for example, Mars and Europa — harbor life, making them ideal candidates for future exploration. Later chapters tackle questions regarding life beyond the solar system and describe techniques that could be used to search for it. Grady consistently provides the basic background information and introduces important concepts in easy-to-understand terms using simple, colorful diagrams.

Earth serves as the prototype environment for the emergence of life, and readers learn that the basic conditions needed for microorganisms to evolve evidently abound on many worlds. New discoveries on Earth — such as extremophile life forms capable of thriving in hostile environments — redefine the acceptable habitat parameters necessary for life.

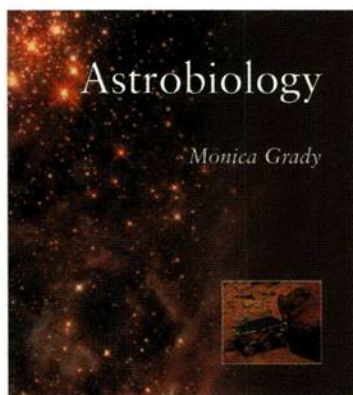
Astrobiology draws expertise from diverse fields like microbiology, astronomy, and geology. However, because the book contains fewer than 100 pages, Grady manages only to skim over many basic points of this multidisciplinary science. She approaches the topic from an astronomical and geological perspective rather than a biological one.

Unfortunately, vital subjects like evolution and genetics are all but ignored and the text occasionally loses focus. For example, readers encounter a two-page history of the naming process of past space missions in the heart of a chapter dealing with exploring for life within the solar system.

None of the information presented is new; nevertheless, Grady's book offers an excellent — albeit brief — introduction to astrobiology. The main attractions are the stunning illustrations, ranging from single-celled creatures to the most recent snapshots from planetary probes.

Although Grady is actively involved in the quest to find life in the universe (called by many the Holy Grail of space exploration), in *Astrobiology*, she tackles this broad subject as a simple primer for the uninitiated. —

Andrew S. Fazekas is a science communicator from Pierrefonds, Quebec, Canada.



Astronomy and Astrophysics in the New Millennium

National Research Council, 246 pages, National Academy Press, Washington, D.C.; 2001; ISBN 0-309-07031-7; softcover, \$34.95.

Your tax dollars at work. That's my suggestion for an alternative title to *Astronomy and Astrophysics in the New Millennium*. This exhaustive report by the National Research Council (NRC) provides a ten-year proactive assessment of the future of space- and ground-based astronomy and astrophysics. It focuses on the efficacy of proposed and existing programs, their organizational infrastructure, and the educational aspects to such endeavors, and contains suggestions for development of new technologies.

An evaluation of NASA and NSF (National Science Foundation) objectives, including their complementary roles in flight programs and missions versus basic research, respectively, is also covered.

Overall, nine panels from various astronomical disciplines submitted

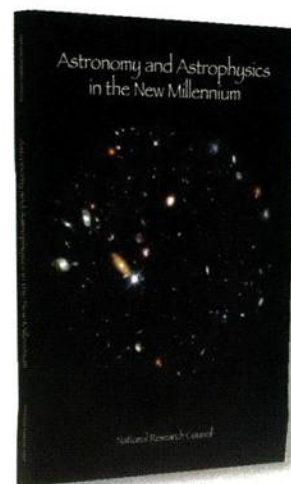
advice and recommendations to the NRC's Astronomy and Astrophysics Survey Committee (AASC).

Seven science panels, composed of experts from leading universities and research centers, concentrated on the following subjects: high-energy astrophysics from space; ground-based optical and infrared astronomy; particle, nuclear, and gravitational-wave astrophysics; radio and submillimeter-wave astronomy; solar astronomy; theory, computation, and data exploration; and space-based ultraviolet, optical, and infrared astronomy. Two other panels prepared input from an educational and "benefits to the nation" standpoint. Additionally, the AASC consulted widely with the astronomical and astrophysical community at large to incorporate goals and establish priorities among domestic and international collaborations. The final AASC recommendations presented encompass achievements, discoveries, and technological advancements from the four previous NRC decadal surveys of 1964, 1972, 1982 and 1991.

Although reading such a compilation may sound like a sure cure for insomnia, it's not. Instead, *Astronomy and Astrophysics in the New Millennium* provides interesting, educational information to scientists and general readers alike. If you want to learn about the government's astronomical policies and goals — as well as what we've accomplished so far and where we're going from here — this book tells you.

For once, most taxpayers would agree that this was money well spent.

— Carol Ryback, associate editor



The Webweaver Picks

by Richard Bartlett

Southern Hemisphere Observatories

Surprise your family with a summer vacation trip to the Southern Hemisphere this year. Sure, it's winter there, but imagine Sagittarius and Scorpius high in the sky, rather than lurking close to the horizon. And don't worry about transporting your telescope all that way — the observatories and planetaria down under have bigger toys for you to play with. If you can't travel there physically, consider a virtual trip on the Internet instead.

Let's begin with New Zealand. The Carter Observatory is located in Wellington and online at <http://www.carterobs.ac.nz>. This superb website is both pleasant to look at and easy to navigate. (However, at last press time, the night sky events page needed updating and no star maps were available online.) The observatory's hour-long planetarium shows include a guided tour of the night sky, which helps



you later that evening as you peer through either of the observatory's two telescopes. These observing sessions last 30 minutes. Make sure to book your space in advance; group size is limited to 12 per scope. Remember that observing sessions are weather-dependent.

Auckland's Stardome Observatory website, <http://www.stardome.org.nz>, focuses on recent astronomical events and includes the current weather satellite image.

Families traveling to Auckland should try to catch one of Stardome's planetarium shows. Private groups and corporations can reserve exclusive dates for planetarium activities, and the 20-inch

(80mm) Zeiss telescope is available for observation sessions as well.

Moving west, we come to New Zealand's neighbor, Australia, and the Powerhouse Museum in Sydney. The observatory is home to a 16-inch scope used during the planetarium shows. A robotic scope on the museum's roof allows outside groups



to observe the sky remotely. Ambitious visitors might like to enroll in the observatory's telescope-making course. Go to <http://www.pbm.gov.au/observe> for further information.

On the western coast we find Australia's most isolated city: Perth. Its observatory is online at <http://www.wa.gov.au/perthobs>. It's a very basic site with text-heavy pages. The observatory is home to several large scopes, with five Schmidt-Cassegrains available for public use. Daytime tours of the observatory are scheduled during one week in the month around the full moon, with nighttime tours arranged around the first and last quarter moons. Book space on these tours in advance.



Let's head west from Australia until we hit the next major continent: Africa. The South African Astronomical Observatory site, <http://www.saa.ac.za>, contains a number of interesting pages. For example, it gives helpful advice on how to pursue astronomy as a career.

You'll also find a page of stories and images relating to African star lore, current astronomical events, observatory press releases and newsletters, plus links for further

information on the upcoming solar eclipse visible from Africa.

But what about the observatory itself? Aside from the ongoing research, seminars, and conferences, visitors can tour the facilities at two locations, Cape Town and Sutherland. The Cape Town site is open to the public every second Saturday of the month starting at 8 P.M. and includes use of the scopes. The Sutherland site is only open on Wednesday, Thursday, and Saturday afternoons. Nighttime tours aren't available to the public.

If you want to take a look at the future of South African astronomy, you'll need SALT — the South African Large Telescope, just outside Sutherland. This joint venture of South African, German, Polish, American, New Zealand and U.K. partners is currently building the largest single telescope in the Southern Hemisphere with a mirror array 11 meters in diameter.

Check it out at <http://www.salt.ac.za/>. It won't see first light until December 2004, but visitors are welcome to watch the progress. Boxes along the side of the website page briefly explain stars and planets.

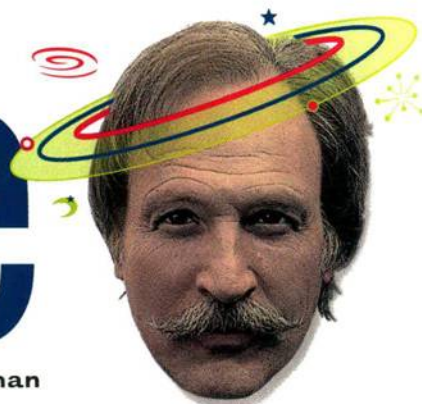


Ever wonder what it's like to work at one of the European Southern Observatory (ESO) sites? Although headquartered near Munich, the observatories are located in Chile at La Silla (<http://www.la.silla.eso.org/>) and Paranal (<http://www.eso.org/paranal/>), home of the Very Large Telescope. As offshoots of ESO's main site, these websites share similar designs, striking a good balance between text and graphics. Only journalists and professional astronomers are allowed at the observatories, but it's still fun to visit the websites.

Next month's Webweaver will focus on observatories north of the equator. — Visit Richard's StarLore website at <http://www.starlore.net>.

■ strange Universe

by Bob Berman



Number and Number

April is a time of serious thoughts about numbers. Ordinary folk now join astronomers with numerological obsessions, and confusion is part of the process. People correctly associate space science with endless numerals expressing redshift or orbital velocity and, like the tax code, they make many brains number and number as they struggle with “9th magnitude HDE226868’s distance of 400 parsecs.”

Astronomers love that kind of stuff. We’ll take all the figures you care to throw at us. But the average person is ignorant of even simple stats such as the diameter of the moon or the distance to Mars. Even the sun’s distance was considered so esoteric that it was the very first million-dollar question on the popular TV show, “Who Wants to be a Millionaire?” Most folks can recite just a single celestial numeral: nine.

This sole digit that everyone knows is the number of planets in the solar system. That probably explains the concern about Pluto’s status. When New York’s Hayden Planetarium of the Rose Center for Earth and Space decided to display just eight planets to emphasize the controversy surrounding Pluto’s classification, teachers were dismayed. “What do we tell the kids? Eight or nine?” The solitary celestial numeral in the public’s brain was now yanked away or at least made iffy, violating the prohibition against mental cruelty.

America’s astro-numeral confusion emerges frequently, as when people exclaim that they camped under a sky filled with “millions of stars.” (The true number is around 3,000.) Or when they mention that those stars are “millions of light-years away.” (The average distance is 100 light-years.)

Then we have often-repeated “facts” like: “There are more stars in the universe than all the grains of sand on Earth.” Who hasn’t heard this? Is it really true? No author mentioning this numerological tidbit ever explains or substantiates it.

Recently, while awaiting a FedEx delivery man confused by my rural region’s total absence of house numbers (because there’s never been mail service here), I idled away an hour overcompensating for his lack of seeing numerals by working out whether the universe has more stars or more grains of sand. Care to guess?

First I weighed and counted a tenth of a gram of typical sand grains. (They come in various sizes.) I made a few

assumptions. (Sand covers half of Earth’s surface when you include sea-beds, to a depth of ten feet.) I figured what fraction this represents of Earth’s entire weight of 5,980,000,000,000,000,000,000,000 grams (one ten-millionth), and came up with an approximate number of sand grains: one followed by 23 zeroes. A hundred billion trillion, if you care to say it.

Stars are easier to estimate. They still require a few assumptions: Some 100 billion galaxies are known, but the Milky Way is much larger than average so our mass of 100 billion suns per galaxy is atypical. Also, most stars are less massive than ours. And there are other things here too, like dark matter, so let’s assume 400 billion suns in our galaxy. If the typical dwarf galaxy has one-tenth as many stars (since it has one-tenth our mass), the total star-count is roughly a hundred million trillion. So there are not more stars than grains of sand. There’s a thousand times more sand-grains on Earth than stars in the known universe.

However, some books say “more stars than the sand on all of Earth’s beaches.” That would ignore undersea sand, which is most of it. If we then conservatively assume that a thousand times more sand lies under the ocean than is exposed on land, then stars and sand grains come out being about even. But what about desert sand? Count it in or out? The issue remains rather unclear and after all that, the delivery man still hasn’t arrived.

(Readers burdened with excessive leisure time who know more about sand than I do or those who can dream up a better methodology are invited to send in their own answers to this sand/star business.)

But the fault is not always in the stars. Scientists love using non-intuitive numerical units. The light-year, for example, is a wonderful measurement of distance that makes sense and gives meaning to the cosmos. If the star Vega is 25 light-years away, we know that its image traveled that long to reach us. Throw in light’s amazing constancy and it’s obvious why a light-year is such a perfect, graspable unit of distance. The problem, apparently, is that it was too easy. So, sure enough, bingo, astronomy texts and research papers switched a few decades ago to the exclusive use of parsec and megaparsec for distance expression. Its basis is the annual arcsecond parallax

of various stars — intuitively useful to almost nobody outside the socially isolating field of astrometrics.

Gradually, however, serious astronomers have acquired a mental “feel” for the meaning of, say, 20 kiloparsecs — a sure sign that it’s time for physicists to switch to an even more obscure unit. How about “terafurlongs?” Expressing distance in trillions of furlongs would help ease equestrians and thoroughbred horse owners and trainers into the astronomy pastime. Alpha Centauri is 200 terafurlongs away. It has a nice ring.

For velocity, the “miles per hour” used in popular literature has long been replaced in technical journals with meters per second. If that’s become meaningful, then it too should be abandoned. A new unit for expressing the kind of very slow motion seen around tectonic plates and HMO claim processors might be: Angstroms per fortnight. For more animated phenomena, the modern velocity standard could simply be Angstroms per “femtofortnight.”

Expressing speed in quadrillionths of a fortnight might seem esoteric at first, but it’s wonderfully practical. The space station’s orbital speed happens to be a nice round 1,000 Angstroms per femtofortnight, and a typical freeway speed limit is 4 A/ff.

Metric conversion brings its own bewilderment. The base-ten system is logical and has become nearly universal. But nobody should imagine that the meter is more intuitive or friendly than the foot or inch, rooted as it is in human physiology and personal experience. Indeed the meter, originally one 10-millionth the distance from the equator to either Pole, is now a totally abstruse unit defined by the distance light travels in 1/299,792,458th of a second. And that’s not a particularly sensible measure.

A foot, by contrast, happens to be nearly the distance that light travels in a nanosecond (a billionth of a second). Simple! We probably should go metric, but not because its fundamental units are better or more intuitive. They’re not.

The bottom line has always been making sense of the universe. Though dealing with taxes this month may not be a particularly helpful step in that direction, numbers will remain so crucial in comprehending the cosmos, we’ll never be able to write them off. **A**

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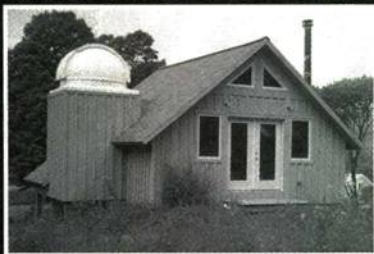


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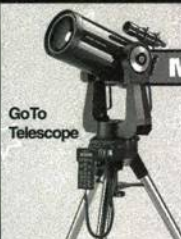
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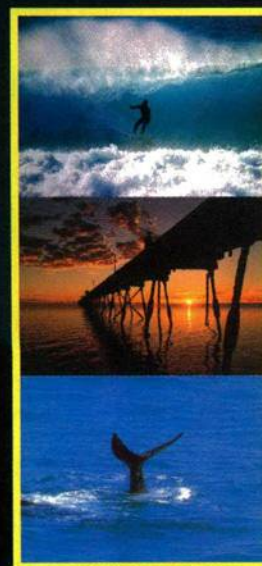
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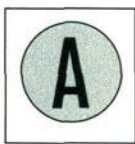
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stronomy Day is an occasion for planetaria, observatories, astronomy clubs, and other skygazers to bring the fun and majesty of astronomy to the public. Celebrated on April 20, the day will afford many people their first opportunity to peek through an eyepiece or enjoy a sky show. With this public relations event, amateurs and professionals alike are able to not only share their love, but also answer questions or encourage the public to participate in astronomy.

Astronomy Day, part of a week of festivities, is held yearly between mid-April and mid-May on the Saturday near the first quarter moon. Astronomy Week starts the preceding Monday and ends the following Sunday.

Contact local museums, universities, observatories, astronomy clubs, or parks to find out what Astronomy Day and Week activities will be held in your area. For more listings and updates, check our website regularly at www.astronomy.com.

MARCH 14-17

Kisatchie Star Party

Kisatchie National Forest, Louisiana. Sponsored by the Baton Rouge Astronomical Society. This year's theme will be "Back to Basics" with lectures and workshops dedicated to some basic astronomical topics. Admission is \$10 for adults and free for those under 18. For more information, contact Don Weinell, weinell@eatel.net; website, <http://www.eatel.net/~weinell/>.

APRIL 6

StarConn 2002

Wesleyan University, Middletown, Connecticut. The Astronomical Society of Greater Hartford will sponsor StarConn 2002, its 16th annual convention. The one-day event is a symposium of many famous lecturers in various fields of astronomy. For more information, visit www.asgh.org.

APRIL 9

Free Planetarium Show

Gary E. Sampson Planetarium, Wauwatosa West High School, Wauwatosa, Wisconsin. 7 P.M. Seating is limited; for



Tim Kimbler

On Astronomy Day many amateurs will gather together with their scopes to gaze at the sky.

reservations call (414) 773-3007. The free, one-hour shows will take place on the second Tuesday of every month throughout the school year. For more information, contact Mary Pat Pfeil, (414) 773-1022.

APRIL 10-13

Mid-South Star Gaze

Rainwater Observatory, French Camp, Mississippi. The Mid-South Star Gaze is a weekend conference and gathering of amateur astronomers who come to share, listen to outside speakers, and observe together. This annual meeting is designed for amateur astronomers and anyone interested in learning astronomy. The event includes a teacher workshop, lectures, and informal deep-sky observing. Co-sponsors of this event are the Rainwater Astronomical Association, the Jackson Astronomical Association, SLO of Memphis, and the Memphis Astronomical Society. The cost of attending the conference is \$18. For more information, contact (662) 547-6865; e-mail, rainwater@astronomers.org.

APRIL 12

Is There a Solar Storm in Your Future?

Universe Theater, Adler Planetarium and Astronomy Museum, Chicago, Illinois. 7 P.M. The sun is not a quiet star.

During the current sunspot maximum period it ejects power blasts of plasma and radiation, which can produce electrical power blackouts, satellite damage and even harmful radiation effects to airline passengers and crew members. In his lecture, Sten Odenwald will present evidence for past problems and the future prospects for our increased vulnerability to solar storms. For more information, contact (312) 922-STAR; website, <http://www.adlerplanetarium.org>.

APRIL 12-13

Central Texas Star Party

Eagle Eye Observatory, Canyon of the Eagles Lodge and State Park, near Burnet, Texas. Sponsored by the Austin Astronomical Society, this twice-yearly star party affords amateurs an opportunity to observe under some of the darkest skies in Texas. Entry to the park is \$5 for adults, \$4 for senior citizens, and free for children under 14. Lodging is available from the park. For more information, e-mail, aas-info@kirchhof.com; website, <http://www.austinastro.org>.

APRIL 12-13

Lake Whitney State Park Astronomy Day Celebration

Lake Whitney State Park, Whitney,

Texas. Celebrate Astronomy Day with telescope making, videos, games, guest speakers, and telescope observations. For more information, visit their website, <http://whitney-astro.com>.

APRIL 19-22

University of Arizona Alumni Association Astronomy Camp

Catalina Observatories, Tucson, Arizona. Sponsored by the University of Arizona Alumni Association, this is a combined camp for both beginner and advanced adult astronomers. For more information, contact Don McCarthy, (520) 621-4079; mail, 933 N. Cherry Avenue, Tucson, Arizona 85721-0065; e-mail, dmccarthy@as.arizona.edu; website, <http://ethel.as.arizona.edu/astrocamp>.

APRIL 20

Boston Museum of Science Astronomy Day

Museum of Science, Boston, Massachusetts. Dynamic exhibits, programs, exciting hands-on activities and demonstrations will be presented throughout the day. In the evening (weather permitting) there will be a star party on the garage's roof. For more information, contact Noreen Grice, (617) 589-0273; e-mail, ngrice@mos.org.

APRIL 20

Dallas Astronomy Day

Richland College, Dallas, Texas. The Texas Astronomical Society of Dallas will be hosting Astronomy Day 2002 at Richland College in Dallas, Texas. Events begin at 11 A.M. and include hourly planetarium shows, lectures, mirror grinding and telescope making presentations, multimedia exhibits, hands-on activities for kids, and telescope viewing until 11 P.M. For more information, contact Dan Doyle, P.O. Box 703247, Dallas, TX 75370-3247; (972) 394-5694; e-mail, starmandan@hotmail.com; website, <http://www.texasastro.org>. **A**

CONTACT

Please submit club announcements four months in advance to Looking Ahead, *Astronomy*, P.O. Box 1612, Waukesha, WI 53187, or jmcgovern@astronomy.com. Look for additional events at <http://www.astronomy.com>.

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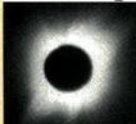
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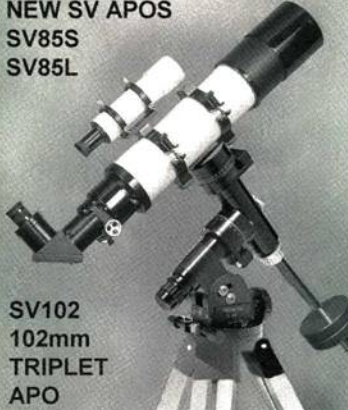


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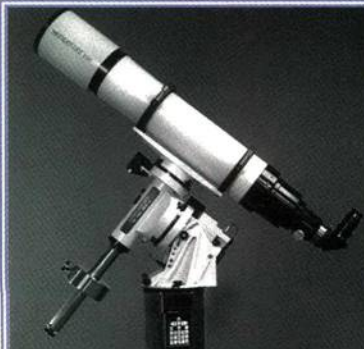
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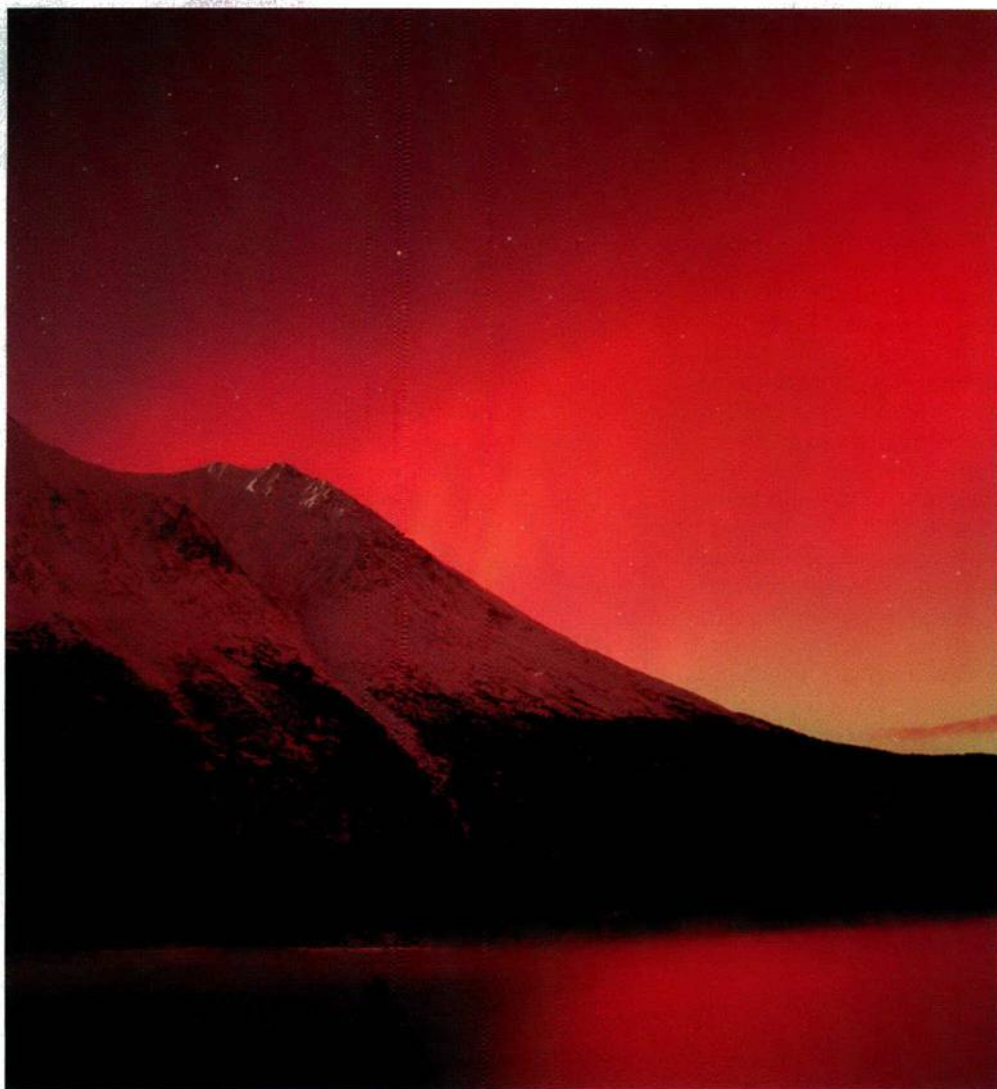
Winter Nights and Northern Lights

► On the night of November 6, I prepared for a blissfully sleepless night outdoors, watching the arctic sky come alive with auroral color.

Around 6 P.M., I was both disappointed and excited — the sky over my town, Skagway, Alaska, was mostly covered in clouds, but they glowed red from the intensely bright aurora that burned above them. I jumped in the truck and drove north, hoping to find clear skies. After driving 40 miles, I finally emerged under stars.

I pulled off the road next to a large glacially carved lake that had yet to freeze for the winter. As I got out of the truck, surging red waves of light like I had never seen before engulfed me. After two hours, the display never dimmed or changed color. When clouds finally cloaked the sky, I happily resigned to drive back to town, more than enthralled with one of the most beautiful and unusual displays I had ever seen. Coasting down the south side of the mountain pass, I was amazed to see that skies above Skagway were clear. I arrived home around midnight and decided to hike to a rocky finger of land that juts out into the deep salt-water fjord that meets the town to the south.

I sat on a huge boulder at the very tip of the peninsula. Calm waters reflected the sky and shimmered red;



Alaskan Aurora

MICHAEL KLENSCH
(28mm lens at f/1.8, Fuji 400 ISO
Superia film, 15-second exposure
taken near the Alaska/
Canada border)

Moon Rising over Quarry

ERIC KALIX
(50mm lens at f/4, Kodak Max ISO
800 film, 15-second exposure)



I could barely tell where the sky began. Suddenly, the stillness was broken by a familiar sound — a long, deep exhalation of whale breath. I wasn't alone. Red aurora-reflected ripples traveled away from the humpback as she slid back into her liquid realm. A few moments later, I heard another breath, shorter and higher pitched, followed by singing; the mother whale was joined by her calf for a midnight swim. Were they curious to know why their normally inky black surrounding shone red? Then came more familiar sounds, as a number of seals emerged to breathe the cold night air. It seemed we were all aware of each other's presence and decided to collectively share in this fantasy. I thought of the native legend on Nunivak Island, Alaska, where it is believed the aurora is a game of celestial football played by spirit walruses. Were their kin simply showing up to enjoy the game?

Skies remained alive with dancing light and my marine companions were still swimming through glowing waters when I headed home at 4 A.M. It was time for sleep. Yet I knew nothing I could dream would compare to this. **A**

Michael Klensch is an avid astrophotographer in Alaska.

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NGC 1398

TED WOLFE

(12.5-inch Ritchey-Chrétien at f/7, ST8e CCD camera, composite of six 7-minute exposures)

Lunar Closeup

RENÉ LALONDE

(11-inch SCT at f/46, Nikon CoolPix 950 digital camera)





Above: Aurora and Moon

MICHAEL KLENSCH
(24mm lens at f/4, Fuji 400 ISO
Superia film, 15-second
exposure taken near
Alaska/Canada border)

**Above, right: Partial Eclipse
and Pelican over Tampa Bay**

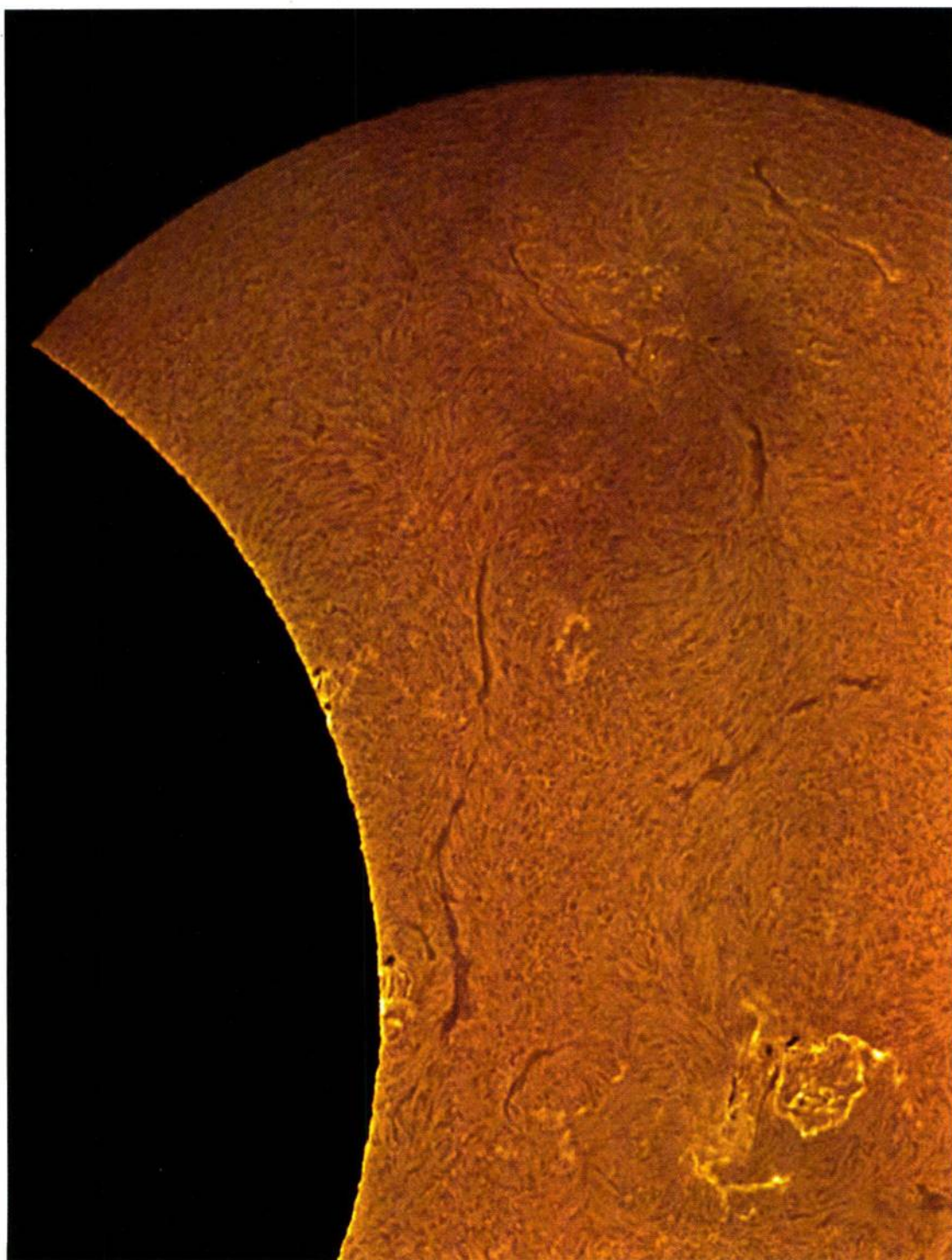
ED SCOTT
(28mm lens at f/3.5, Canon D30
digital camera, taken December
14, 2001)

**Left: Aurora over Grand
Canyon**

WIM WENSELEERS
(50mm lens at f/1.8, Fuji Superia
800 film, taken November 5, 2001)



This month's best astrophoto



Partial Solar Eclipse over Florida

JACK AND ALICE NEWTON

(7-inch apochromatic refractor at f/9, Pictor CCD camera, taken December 14, 2001)

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